GREATER YELLOWSTONE

AN ECOSYSTEM AT RISK

Unending Population Growth and Development Threaten the Greater Yellowstone Ecosystem

By Leon Kolankiewicz, with Roy Beck and Eric A. Ruark
Foreword by Todd Wilkinson

Autumn 2024

A scientific study by

NumbersUSA

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Cover Photo by Holly Pippel: Bison overlooking the rapidly growing Gallatin Valley of Montana, north of Yellowstone National Park. This icon of the American West (as well as public wildlife that benefit from habitat protection) inhabits the Flying D Ranch, which is protected by one of the largest conservation easements in the country. The easement provides a buffering effect against sprawl in one of the fastest growing rural counties in the Lower 48, whose continued landscape health is critical to maintaining wildlife populations in the globally-renowned Greater Yellowstone Ecosystem.

NumbersUSA

About the Authors

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ROY BECK was one of the nation's first environment-beat newspaper reporters in the 1960s. A graduate of the University of Missouri School of Journalism, he won national recognition for his coverage of urban expansion issues. A former Washington bureau chief for a chain of daily newspapers, he is the author of five public policy books, including *Recharting America's Future*, and the latest, *Back of The Hiring Line: a 200-year history of immigration surges, employer bias, and depression of Black wealth*. His articles have appeared in scores of magazines, newspapers and journals. He has lectured widely on the ethical aspects of U.S. population issues and testified before Congress on many occasions. He has co-authored more than a dozen studies on sprawl in the last two decades. He founded NumbersUSA in 1996 to educate the public on the recommendations of two federal commissions on population and environmental sustainability and on economic justice.

ERIC A. RUARK is the Director of Research of NumbersUSA Education & Research Foundation. He attended Virginia Commonwealth University and the University of Maryland, College Park and has a M.S. in modern European history. He has worked as a researcher on U.S. immigration policy since 2008 and has written extensively on the effects of population growth. His work has been cited in national and international media reports and in his testimony in the U.S. Senate. He is an original signatory in the International Network for Immigration Research.

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How Sprawl and Expanding Human Imprint Are Threatening the Survival of the Greater Yellowstone Bioregion

Foreword by Todd Wilkinson

In nearly four decades of writing about wildlife conservation issues and their intersection with human-built environments, I've often confronted this challenge: how to make the consequences of population growth more understandable to readers who believe "growth just happens" to both places and people. Routinely, they harbor the mistaken impression there's little that can be done to mitigate it. Few, in fact, do much reflecting on their own ecological footprint and how it ripples collectively on a landscape level.

A few short years ago, I was working on an investigative story about the impacts of inward migration— of Americans moving from one place to another for largely lifestyle considerations. Their primary motives were wanting to escape crowded urban areas, to take advantage of remote working options, and, frequently, out of a desire to "live closer to nature."

The focus of my narrative was not on just any region. The area of interest was the Greater Yellowstone Ecosystem, a vast complex of public and private lands readily visible from my home in Bozeman, Montana.

Greater Yellowstone, if you're unfamiliar with it, has Yellowstone, the first national park in the world, at its geographic heart. The ecosystem that encompasses the park is today considered the most iconic wildlife-rich bioregion in the Lower 48 states, renowned especially for its concentration and diversity of large free-ranging native mammal species rescued from near-annihilation at the end of the 19th century.

There are compelling scientific reasons why Greater Yellowstone is often compared with another famous reference point for large mammals—the Serengeti Plain in East Africa.

Somewhat surprisingly, I've discovered, many Americans are more familiar with species on the Serengeti, owed to the popular Disney animated film, *The Lion King*, than they are with Greater Yellowstone. Many are shocked to discover that equal levels of drama can be found in the backyard of the West. One can watch howling wolves hunting bugling elk; see wild herds of bison and pretend it's a scene from 200 years in the past; savor the presence of famous Jackson Hole Grizzly 399 and generations of her cubs; and stroll through the ethereal geothermal basins of Yellowstone and believe you're on another planet.

Here, where I live, there are Yellowstone and neighboring Grand Teton National Park. Encircling them are five different national forests, three national wildlife refuges, a large sweep of federal land administered by the Bureau of Land Management and the Wind

River Indian Reservation, home to the Northern Arapaho and Eastern Shoshone nations. Notably, Wind River is almost identical in size to Yellowstone and its 2.2 million acres, which at roughly 3,500 square miles is larger than Rhode Island and Delaware combined.

In all, of Greater Yellowstone's roughly 23 million acres, three quarters of it is public land and the last quarter is comprised of private property, including working farms and ranches.

While the private land component is a fraction of the amount of public acreage that belongs to all American citizens, it serves a critical ecological function. Located mostly in lower-elevation river valleys, these private lands are like vital connective tissue holding together the superstructure of public lands. Wildlife do not recognize nor abide artificial human boundaries put down on maps. The survival of more than four-fifths of Greater Yellowstone's biological diversity involving animals larger than insects relies on habitat found on private land, permanently or seasonally.

In the larger picture of the American West, Greater Yellowstone resides at the intersection of three states—Wyoming, Montana and Idaho. Rising from it are the headwaters of three major U.S. river systems—the Yellowstone-Missouri-Mississippi; the Snake-Columbia; and the Green-Colorado that, in turn, empty, respectively, into the Atlantic, the Pacific, and the waters of Baja, Mexico.

Historically, Greater Yellowstone has benefitted from four factors: its geographic remoteness, sheer mass of public lands, low human population and the fact that the preponderance of private land was either agricultural or undeveloped. Three of those variables—remoteness, low human population and development that is clustered primarily around cities and towns—no longer exist.

As I was doing my research about the impacts of population growth and the corresponding expanding footprint of development in Greater Yellowstone, I met with a highly respected conservation biologist named Brent Brock who had devised a computer modeling program that he called Wild Planner. During one of our many visits, he invited me over to his computer and said, "Hey, look at this."

In rapid succession, Brock typed in data that came from a number of reputable sources ranging from the U.S. Census Bureau to state cadastral maps. Soon we were looking at the proliferation of recent residential subdivisions that had sprouted in exurban areas of three counties – Gallatin, Park and Madison – in the northern tier of Greater Yellowstone. The results were jaw dropping, and then Brock plotted in the likely locations of new development and how they would replace working farms and ranches. It revealed a pattern that, if left unchecked in coming decades, would leave some of Greater Yellowstone's major wildlife migration corridors, important to the movement of elk, pronghorn, mule deer and other species blocked or severely constricted. The longest known migrations for elk, pronghorn and mule deer in the world exist in this ecosystem.

While standing next to Brock, who passed away tragically from cancer in October 2023, I will never forget something this forward-thinking conservation biologist said: “Sprawl kills.” It has an established record of being a destroyer of wild ecosystems and, unless things change, unbridled growth is going to ruin many of the things that still set Greater Yellowstone apart as an American national natural treasure. The most obvious manifestation, Brock said, will be fragmented landscapes that result in wildlife being no longer able to navigate between key seasonal habitats.

Two large landscape thinkers, Dr. Matthew Kauffman, a federal USGS scientist spearheading the Wyoming Migration Initiative, and Dr. Arthur Middleton, based at the University of California-Berkeley, have likened Greater Yellowstone’s migration corridors to the circulatory system of a human body. Block the arteries or passageways leading to the heart or lungs and serious negative consequences are certain.

Where Greater Yellowstone is considered a beacon of modern wildlife conservation globally, touted as the emblem of a healthy intact ecosystem in America and known for its successful rewilding of several species, its legacy, Brock said, could be one of permanent rewilding unless trendlines are altered.

Here, I will invoke the perspective of another big picture thinker, former Yellowstone science chief David Hallac who said there is the usual array of large obvious challenges facing Greater Yellowstone but more insidious is what he calls “death by 10,000 scratches” involving a constant onslaught of new structures, roads, and infrastructure, much of it taking scattershot form across rural lands.

Sprawl kills because it permanently destroys wildlife habitat that is finite and irreplaceable. It erases rare species and leaves wildlife homeless. Sprawl turns family ranchers and farmers into artifacts. As cost of services studies note, it also causes local governments to become submerged in a flood of red ink. And sprawl creates homogenized human spaces that all look the same and lack character.

Assessing the impacts of sprawl is important no matter what the geographical setting, but in here it takes on added significance. Greater Yellowstone is the only bioregion remaining in the Lower 48 states with all of its original species that were present in 1491, the year before Europeans arrived on the continent. A crucial question readers should ask is: why have the caliber of wildlife attributes present Greater Yellowstone been lost mostly everywhere else?

Once you’ve pondered that query, pay special attention now to this study you hold in your hands—a scientific examination/overview of how the rapidly-expanding human footprint on private land in Greater Yellowstone is shaping the prospects for species survival today and in the future.

To date, few studies have taken a deep dive look at the intensifying effects of sprawl on a wildland-wildlife ecosystem like Greater Yellowstone. Not only is such an examination

long overdue, but it is especially poignant—and timely. Inward population growth and an ever expanding human footprint were serious concerns before the arrival of Covid. But during the pandemic three things happened: the pace of exurban sprawl on private rural land accelerated as more newcomers moved into the region; subdivisions supplanted former farms and ranches like never before; and the intensity of outdoor recreation pressure on public lands increased markedly.

The result is wildlife being squeezed out of optimal habitat formerly available on private land, and recreation pressure displacing species on public land. On top of it, whether one believes that climate change is caused by humans or not, meteorological data show the region has become warmer and drier; a testament to that is not only that there are 30 additional days each year in which the temperature doesn't fall below freezing, but larger forests fires are becoming more common. Dr. Cathy Whitlock, a Montana ecologist and fellow with the National Academy of Sciences, led a series of reports on climate change, including one for Greater Yellowstone that forecasts major ecological disruptions related to water availability and use, fires and drought.

Why is the risk of property loss growing every day? Because more people than ever before are building their dream homes inside the forested wildland-urban interface, which also happens to represent a critical zone of connectivity for species moving between public and private lands.

One may wonder: what's the connection between healthy ecology and economy in Greater Yellowstone? Every year, the National Park Service releases findings of an annual assessment gauging economic impact. One recent analysis found that Yellowstone and Grand Teton parks alone generated $1.5 billion in economic activity for the surrounding communities and that commerce was responsible for creation of 15,000 jobs. Besides the allure of seeing Old Faithful Geyser erupt, grizzly bear and wolf watching opportunities were the top attractions.

In 1995, researcher William Newmark published a peer-reviewed paper titled *Extinction of Mammal Populations in Western North American National Parks*. He noted that even in other large parks similar to Yellowstone, species over time still vanished. The reason was they were inadequate, by themselves, to sustain wide-ranging terrestrial species.

In 2023, Newmark and colleagues published an updated analysis in the respected journal, *Nature*, and again observed that big parks aren't big enough. In particular, he alluded to national parks becoming isolated and islandized inside a sea of sprawl: "Protected areas are the cornerstone of biodiversity conservation worldwide. Yet the capacity of most protected areas to conserve biodiversity over the long-term is under threat from many factors including habitat loss and fragmentation, climate change, and over-exploitation of wildlife populations. Of these threats, habitat loss and fragmentation on lands adjacent to protected areas are the most immediate and overarching threats facing most national parks and related reserves in western North America. As a result, most parks and related reserves in western North America are becoming increasingly spatially and functionally isolated in a matrix of human-altered habitats. This is

particularly problematic because few parks and related reserves worldwide are large enough to conserve intact plant and animal communities and many large-scale ecological processes, such as mammal migrations and disturbance regimes [such as wildfires, floods, droughts and disease outbreaks affecting species]."

Yellowstone and Grand Teton are not drive-thru zoos. They have no fences encircling their perimeters. As Newmark noted, these national parks are not big enough, by themselves, to maintain the survival of species found inside them. Wildlife needs room to roam. The vast majority of species in Greater Yellowstone rely upon private land habitat to stay alive and indeed private lands function as critical passageways between public lands.

When it comes to migration routes and particularly "pinch points" where the size of the corridor is narrow, a new subdivision of just 100 homes and organized as 20-acre ranchettes could, in some places, impair the ability of wildlife to migrate. This is an example of what Kauffman and Middleton say is analogous to a blood clot in a human body, blocking the circulatory system.

Allow me to offer some added context. A few decades ago, a group of researchers concluded that a new residence and outbuildings constructed on a section of land (640 acres or one square mile) would displace a grizzly bear mother and cubs. It's important to note that a different scientific analysis showed that secure habitat which supports grizzlies is beneficial to more than 230 other species of mammals, birds, fish, and amphibians. During a recent chat, the head of the Gallatin Valley Land Trust told me that for every acre being protected through conservation easements, two acres are being lost to development—and that trend does not include the amount of acreage that already is covered by leapfrog sprawl. That ratio is comparable to many valleys in Greater Yellowstone.

Only a generation ago, the total human population for the entire ecosystem was around 460,000. In 2017, I met with population demographers and planners and wrote a story about growth trends in Greater Yellowstone. Remember, this was prior to Covid and the effects it brought. I turned first to Bozeman and Gallatin County which had a combined population of about 110,000.

Less than a decade ago, Bozeman and Gallatin County were growing at rates of around three to four percent annually. Based on a conservative trajectory of three percent, that meant that Bozeman/Gallatin would double in population in 24 years, meaning that it would have a population equal to today's Salt Lake City proper. It also means that if that growth rate continues, it would double again in 48 years, becoming the size of Minneapolis proper (440,000) by around 2065.

In the southern half of Greater Yellowstone, a corridor of towns between Idaho Falls, Idaho, running through Jackson Hole and connecting other mountain valley communities, there is today a population roughly equivalent to the size of Salt Lake City proper (250,000). That total volume of humans is expected to double within a

generation. In addition, there are many spillover effects happening from Bozeman and Jackson Hole into neighboring valleys.

In recent years, especially during the Covid exodus of people moving to Greater Yellowstone, the number has surged. The truth is that the influx of people into any rural valley need not be that explosive for major negative ecological impacts to register. The impacts of suburbanization are permanent. Subdivisions do not go away and their cumulative effects only deepen over time to the point that, eventually, species simply disappear and human tolerance for having them in their backyards also goes away. That's why the consequences of de-wilding a previously wild landscape are so pervasive.

Sure, you might have highly-adaptable white-tailed deer and coyotes roaming golf course fairways on land that was previously a ranch with a tiny imprint of buildings, but gone is secure habitat for more sensitive species such as free-ranging elk, mule deer, pronghorn, moose, grizzlies, wolves, bighorn sheep and wolverines. No matter how one feels about livestock, working ranches with cows are far better than a meadow covered in condos, for as long as the land base is intact, wildness has a better chance of persisting and it represents places where re-wilding can occur.

Recall again my earlier reference made by scientist David Hallac about Greater Yellowstone suffering a death by 10,000 scratches. While individually each of these scratches may be insignificant, it's the cumulative effects that exact a mighty consequential toll.

Public land managers can take steps to address the impacts of traditional natural resource extraction or lessen the pressure of outdoor recreation on wildlife by limiting numbers of users, but on private land, infrastructures of concrete, steel, wood and asphalt cannot be undone. Every new subdivision comes replete with buildings, driveways, fences, non-native vegetation, roaming and barking dogs, domestic cats that kill songbirds, non-natural foods that can serve as wildlife attractants and result in animals getting removed, a cacophony of noises, and light pollution that drowns out of the starry night skies. People who build their dream homes on the edge of national forests and then get worried about fire after the fact often end up logging the forest as a tactic of prevention yet they don't realize it destroys habitat.

I have file drawers full of papers written by leading scientists that speak to the points above. As has been conclusively established, island populations of species disappear at higher rates than those which are sustained over large unfragmented areas. Destruction is subtle and by the time it becomes visible to humans it may be too late to reverse. Newmark and co-authors wrote: "Most species extinctions in habitat remnants, including protected areas, following habitat loss are not immediate, but occur after a time lag. The lag in species loss over time is because many species that occur in habitat remnants do not have viable populations. The delayed loss of species over time in habitat remnants is referred to as relaxation or faunal collapse."

In 2009, Dr. Andrew J. Hansen, a professor of ecology at Montana State University wrote an analysis titled “Species and Habitats Most at Risk in Greater Yellowstone” for the journal *Yellowstone Science*. He shared his ongoing analysis of development patterns at dozens of different sites in the ecosystem.

“Developed land has increased faster than the rate of population growth. While the GYE experienced a 58 percent increase in population from 1970 to 1999, the area of rural lands supporting exurban development increased 350 percent,” Hansen wrote. He noted that riverside habitats, also known as riparian areas, rank among the most important for maintaining biodiversity. “Of the many miles of rivers flowing through private lands in the area, 89 percent of the streamsides are within one mile of homes, farms or cities. Among aspen and willow habitats, critical for wildlife, only 51 percent of those on private lands in the Greater Yellowstone area are more than one mile from those more intense human land uses.”

Hansen laid out a litany of negative cascading effects of sprawl and rural development on a wide range of species and showed that development was occurring disproportionately in exurban settings which still provide high quality wildlife habitat. Chastening is that when I spoke with Dr. Hansen again in 2024, those breathtaking trends that he identified in 2009 accelerated prior to Covid and then erupted during the pandemic. In 2022, Hansen was lead author on a paper, “Informing conservation decisions to target private lands of highest ecological value and risk of loss,” that appeared in the journal *Ecological Applications*. Scientists said protection of the last best remaining private land habitats needs to be prioritized.

What this important study led by Leon Kolankiewicz with Roy Beck and Eric Ruark does is put the permanent ecological costs of sprawl into perspective, clear-mindedly providing an overview that citizens, elected officials, public land managers, private property owners, business people and conservationists can understand. Essentially, it puts us all on the same page. Sorely lacking in the assessment of threats to Greater Yellowstone has been a vision for pondering the future and the consequences of knee-jerk, short-term thinking.

Even if one doesn’t care about wildlife, and something as precious as the ecological well-being of Yellowstone and the wild inheritance that Greater Yellowstone represents to this country, there are compelling reasons why it makes sense to pay attention to poorly-planned growth. Sprawl is the enemy to mom and pop farmers and ranchers, making it incredibly difficult to keep operating at scale. Rural communities have been an invaluable part of local identity. Rural sprawl also represents a financial liability to counties and should be of major concern to elected leaders who pride themselves on being fiscally responsible.

Cost of service studies show that many counties are struggling to meet the added need for expanded law enforcement, fire-fighting, emergency services, road maintenance, water and sewer services that new exurban denizens demand. This means that citizens who are already deeply concerned about how sprawl is already transforming the natural

character of their community are given the added indignity of subsidizing the very kind of sprawl they don't want.

Just as Americans are rightfully concerned about the lack of a coherent immigration policy on the U.S. southern border with Mexico, so, too, are longtime inhabitants of Greater Yellowstone worried the downsides of inward migration to their region. A common lament is that rural valleys prized for their peaceful ambiance, unblighted views and presence of wildlife are being transformed into the kind of sprawl synonymous with the Front Range of the Rockies in Colorado or the west side of the Wasatch pressing north and south of Salt Lake City. There, the kind of wildlife values which still exist in Greater Yellowstone are long gone and no amount of expensive re-wilding can ever recover them.

Here, I wish to offer one last aside. Today, billions upon billions of public and private dollars are being spent trying to restore the ecological function of the Florida Everglades. Billions more are being spent to try to save imperiled wild salmon populations by retro-fitting or tearing down dams that have destroyed ancient spawning runs. In southern California, upwards of $100 million is being spent completing an unprecedented wildlife overpass, across 10 lanes of traffic, to accommodate a relative handful of mountain lions and other species that are barely able to persist in that highly fractured megalopolis. Prominent scientists say the least expensive way of maintaining wild nature is not to mess up what isn't already broken and to prevent de-wilding rather than trying to address it in a reactionary way after the fact.

While NumbersUSA has produced several important analyses on the negative impacts of sprawl, this one, which you now hold in your hands or view on a screen, is arguably one of the most consequential. This study provides an opportunity for those in charge of charting Greater Yellowstone's future to think differently and depart from following the script of growth that has brought the thoughtless ruination of wildlife ecosystems in other places.

Such an overview can be useful as a policy tool for two reasons: First, it helps identify areas of high value to wildlife that need to be protected. Secondly, it highlights places that can be sensibly developed and, in that way, brings predictability, order and better efficiency to elected officials and investors in the business community. Currently, this is *not* happening in Greater Yellowstone, and, in fact, most leaders will admit that the approach to dealing with growth to date has been haphazard, contentious, poorly articulated and not well understood by the public.

Remember this about Greater Yellowstone. Yellowstone National Park, its beating heart, is one of the most recognized place names on Earth. It ranks high on bucket lists of millions of people around the world as an essential destination to visit before they die. It is also a source of common national pride for Americans and an icon of intergenerational pilgrimage whose value has only grown over time and will continue to so long as we keep it healthy.

Before you digest the findings of this unprecedented analysis, let me leave you with a couple of lessons I've learned in writing about conservation on assignments that have taken me around the world. Land conservation typifies what it means to be conservative and it invites us to contemplate how we can do positive things that benefit others beyond the span of our own lives. In the history of the world, there are few examples where conservation has not, over time, demonstrated a profound accruing value in ways too manifold to mention. Finally, there is only one Yellowstone and one Greater Yellowstone Ecosystem. If we can't succeed in protecting this bioregion, then what hope, really, do we have for saving anyplace else?

TODD WILKINSON *has been a professional journalist since 1985 and is recognized nationally for his reporting on the Greater Yellowstone Ecosystem and other wildlands of the world. His work has appeared in dozens of national magazines and newspapers, including* National Geographic*,* The Guardian*,* Christian Science Monitor *and* The Washington Post*. He was won several awards and he has penned several acclaimed books on such topics as scientific whistleblowers, the journey of Ted Turner as an eco-capitalist/philanthropist/conservationist, the life of Jackson Hole Grizzly 399 and several books on art and business. His recent book,* Ripple Effects: How to Save Yellowstone and America's Most Iconic Wildlife Ecosystem*, won three awards. He also is founder of a new conservation journalism site,* Yellowstonian (yellowstonian.org), *devoted to exploring the importance of wildlife and wildness in Greater Yellowstone, the American West and beyond.*

FROM GREATER YELLOWSTONE TO LESSER YELLOWSTONE:

Population Growth, Development, Imperiled Wildlife, and the Fracturing of the Greater Yellowstone Ecosystem

EXECUTIVE SUMMARY

1. GREATER YELLOWSTONE ECOSYSTEM: "AMERICA'S BESIEGED SERENGETI"

"…the mountains and rivers are often unpleasantly crowded, lands that were once open space are now glutted with houses." [Introduction, p. 2]

-- Jack Turner, *Travels in the Greater Yellowstone*, 2008[1]

"…several difficult new problems [confront] the GYE: escalating park visitation, mounting recreation pressures, private land development…"

-- Robert B. Keiter, *Colorado Law Review*, 2020[2]

Figure 1-1. Grand Teton (13,775') in Grand Teton National Park, one of two national parks in the Greater Yellowstone Ecosystem

[1] Jack Turner. 2008. *Travels in the Greater Yellowstone*. St. Martin's Griffin. 288 pp.
[2] Robert B. Keiter. 2020. The Greater Yellowstone Ecosystem Revisited: Law, Science, and the Pursuit of Ecosystem Management in an Iconic Landscape. *University of Colorado Law Review*. Vol. 91, Issue 1. 182 pp.

Law professor Robert B. Keiter has dubbed the Greater Yellowstone Ecosystem (GYE) an "ecological wonderland."[3] Depending on how its boundaries are defined, the GYE spans approximately 23 million acres of wildlands, agricultural lands, and human settlements (**Figure 1-2).** That's an area larger than the state of West Virginia covering 20 counties of three Rocky Mountain states: Wyoming, Montana, and Idaho.

Two of America's most renowned national parks – Yellowstone and Grand Teton – comprise the GYE's core, yet it also encompasses five national forests, three national wildlife refuges, Bureau of Land Management (BLM) lands, tribal lands, more than seven million areas of Congressionally-designated Wilderness, additional roadless Wilderness Study Areas (preserved as de facto wilderness), and importantly for this study, millions of acres of private land.

The GYE embraces multiple mountain ranges, the headwaters of three major Western river basins – Snake/Columbia, Green/Colorado, and Yellowstone/Missouri/Mississippi – unique geothermal features, and extensive coniferous forest, alpine, sagebrush-steppe, and riparian habitats. It possesses spectacular scenery and world-famous wildlife; indeed, with the reintroduction of the once-extirpated timber wolf in 1994, it's the only large ecosystem in the Lower 48 states that once again boasts its pre-1492 endowment of wild vertebrates. These include bison, moose, whitetail and mule deer, elk, bighorn sheep, pronghorn antelope, beaver, wolf, black bear, grizzly bear, wolverine, lynx, bobcat, cougar (mountain lion), beaver, bald eagle, trumpeter swan, sage grouse, and cutthroat trout.

Americans and "Yellowstonians" (residents and neighbors of the Greater Yellowstone Ecosystem) are generally aware of Greater Yellowstone and its significance for iconic wildlife. In late July 2024, in conjunction with this study, the polling company Rasmussen Reports and NumbersUSA conducted two parallel public opinion surveys of 1,128 likely U.S. voters and 829 Idaho, Montana, and Wyoming likely voters to gauge their attitudes about the GYE, wildlife, population growth, and immigration.[4]

In the national poll, 93% of U.S. likely voters had heard of Yellowstone National Park, even though only about a third had ever visited Yellowstone or Grand Teton National Parks:

Have you ever heard of Yellowstone National Park?
93% Yes
5% No
2% Not sure

[3] Ibid.
[4] Rasmussen Reports and NumbersUSA. 2024. Survey of 1,128 US Likely Voters, conducted July 28-29, 2024. Margin of Sampling Error, +/- 3 percentage points with a 95% level of confidence. Appendix D in this report. Rasmussen Reports and NumbersUSA. 2024. Survey of 829 Idaho, Montana, and Wyoming Likely Voters. Conducted July 28-30, 2024. Margin of Sampling Error, +/- 3 percentage points with a 95% level of confidence. Appendix E in this report.

Have you ever visited Yellowstone or Grand Tetons National Parks?
35% Yes
64% No
2% Not sure

Of the 735 U.S. respondents who haven't visited either park, nearly seven in ten wished to:

Would you like to visit Yellowstone or Grand Tetons National Parks?
68% Yes
20% No
12% Not sure

Of the 890 respondents who have visited or want to visit Greater Yellowstone, seeing the wildlife is the main reason or one of the top two reasons for nearly three in four respondents:

How important is the wildlife to those park visits? The main reason you visit, one of the two main reasons, important but not one of the top two reasons, or it is not an important reason to visit?
23% Main reason
51% Top two
23% Important but not top two
3% Not important
0% Not sure

Almost two in three U.S. likely voters were aware of the GYE's uniqueness for wildlife:

Are you aware that the Greater Yellowstone Ecosystem is unique in the Lower 48 States in still having all of its original large wildlife species, including grizzly bears, elk, bison, and wolves?
63% Yes
27% No
10% Not sure

And fully 95 percent believed that it is very or somewhat important that large wildlife continue to thrive in the GYE:

How important to you is it that large wildlife species continue to survive and flourish in the Greater Yellowstone Ecosystem?
70% Very important
25% Somewhat important
4% Not very important
1% Not at all important
1% Not sure

For the likely voters of Idaho, Montana, and Wyoming who were surveyed in late July, the results demonstrate, perhaps unsurprisingly, an even greater familiarity with and appreciation for the large wildlife species of the GYE. Eighty-three percent of ID-MT-WY resident respondents had visited Yellowstone or Grand Tetons National Parks (compared to only 35 percent of national respondents). Of those who hadn't yet done so, 84 percent wished to

(compared to 68 percent of national poll respondents). Most ID-MT-WY residents had visited Yellowstone multiple times, as shown in the responses to this question:

How many times have you visited Yellowstone National Park?
- 18% Once
- 53% 2 to 6 times
- 13% 7 to 12 times
- 16% More than 12 times
- 1% Not sure

Of those who had visited the GYE, wildlife was slightly more important an attraction than for national respondent (79% main or top two reasons versus 74% for U.S. likely voters):

How important is the wildlife to those park visits? The main reason you visit, one of the two main reasons, important but not one of the top two reasons, or it is not an important reason to visit?
- 26% Main reason
- 53% Top two
- 18% Important but not top two
- 3% Not important
- 1% Not sure

A substantially higher percentage (83% versus 63%) of likely ID-MT-WY resident voters was aware of the GYE's uniqueness for large wildlife species than U.S. likely voters:

Are you aware that the Greater Yellowstone Ecosystem is unique in the Lower 48 States in still having all of its original large wildlife species, including grizzly bears, elk, bison, and wolves?
- 83% Yes
- 13% No
- 4% Not sure

In this chapter we explore what makes the GYE so special and summarize the growing threats now encroaching upon its ecological integrity and wild character.

1.1 Intro to the GYE – Iconic Wildlife & Geologic Wonders

Archeological evidence indicates that the first human beings, Paleo-Indians, to discover and inhabit the Yellowstone ecosystem arrived more than 11,000 years ago, while Euro-Americans first set eyes on it in the early 1800s. William Clark, co-leader of the Lewis and Clark Expedition, passed through the region in 1806 during the Corps of Discovery's return journey eastward from the Pacific Ocean. He and Meriwether Lewis had divided the Corps into two groups to explore more territory, and Clark's path took him along the Yellowstone River and through where Livingston, Montana is now located, though some distance north of the source of the Yellowstone.[5]

[5] Yellowstone Volcano Observatory, U.S. Geological Survey. 2022. The Exploration of Yellowstone. Accessed on January 20, 2024 at: https://www.usgs.gov/observatories/yvo/news/exploration-yellowstone.

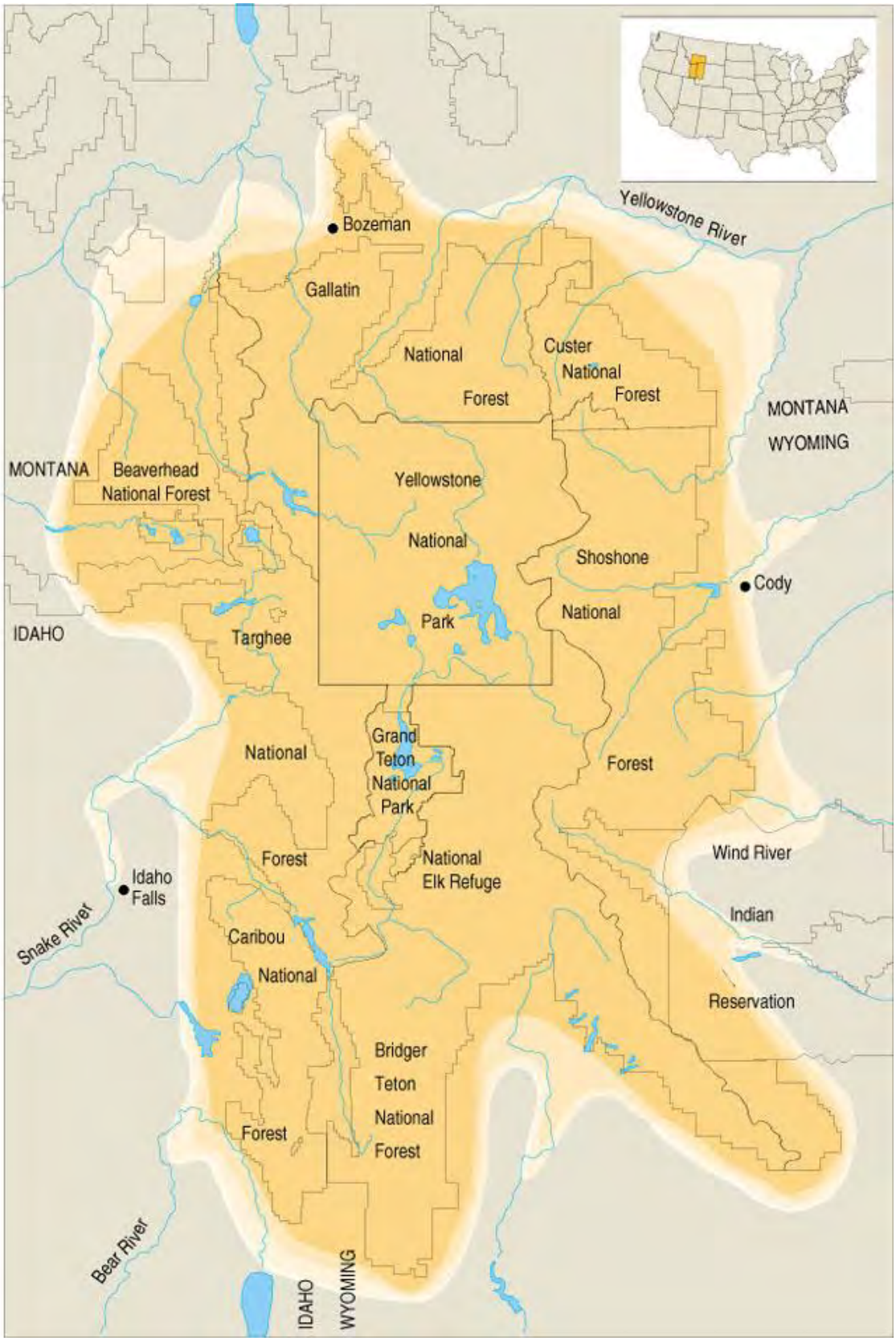

Figure 1-2. Map of the Greater Yellowstone Ecosystem (GYE)
Source: U.S. Geological Survey

While Lewis and Clark themselves never did see what later would become Yellowstone National Park (NP), their Corps of Discovery companion John Colter did. Colter left the Corps before its return to St. Louis to join other trappers already seeking beaver pelts in the Rocky Mountains, in the first of its many "resource rushes." He explored the Yellowstone and Grand Teton areas during the harsh winter of 1807-08, likely becoming the first Euro-American to ever see the GYE's geothermal wonders. As early as the 1820s, Euro-American trappers and hunters – so-called "mountain men" like Jim Bridger – were crisscrossing the GYE in the frenzied but fleeting Rocky Mountain fur trade.[6] Famed Western historian and conservationist Bernard DeVoto wrote about this era in his classic and compelling, Pulitzer Prize-winning 1947 book *Across the Wide Missouri*.[7]

Over the decades in the 19th century, rumors and legends of Yellowstone's geysers (**Figure 1-3**) and hot springs circulated among the few hardy trappers and prospectors who managed to reach this isolated and inaccessible blank spot on the map of the Rocky Mountains. In the 1860s larger parties explored it, and eventually, in 1871, a federally-funded scientific and mapping expedition led by geologist Ferdinand Hayden was mounted. It included nature photographer William Jackson and landscape artist Thomas Moran of the well-known Hudson River School in New York **(Figure 1-4)**. The publicity generated by this expedition led directly to the establishment of Yellowstone NP by Congress and President Ulysses S. Grant in 1872.[8]

Figure 1-3. Old Faithful – the most famous geyser in Yellowstone NP…and the world

[6] Ibid.
[7] Bernard DeVoto. 1947 (1998 paperback). *Across the Wide Missouri*. https://www.amazon.com/Across-Wide-Missouri-Bernard-Devoto/dp/0395924979.
[8] Op cit. Note 4.

Figure 1-4. Thomas Moran, The Grand Canyon of the Yellowstone, 1872, oil on canvas
Credit: U.S. Department of the Interior Museum[9]

Yellowstone was the first declared national park in the entire world, and the start of an American and later worldwide movement to preserve and protect nature's "crown jewels". Today there are 63 national parks in the United States, and some 428 units of the National Park System, including National Monuments, National Historic Sites, National Seashores and Lakeshores, National Recreation Areas, National Battlefields, and so forth. As of 2024, America's National Park System embraces some 84 million acres, with units in each state and many territories.[10] Globally, today there are more than 6,000 national parks in more than 100 countries.[11] And it all started at Yellowstone.

In addition to its geologic wonders, early Euro-American explorers and the Hayden expedition in 1871 marveled at Yellowstone's diverse and abundant wildlife, which of course Indigenous Americans had lived with and depended upon not just for centuries but for millennia. Yellowstone NP itself claims almost 300 species of birds, 16 fish, five amphibians, six reptiles, and 67 mammals – including seven indigenous ungulate species

[9] National Park Service. 2018. Thomas Moran: Artistic Master of the Conservation Movement. Accessed January 20, 2024 at: https://www.nps.gov/articles/thomas-moran.htm.
[10] Rocío Lower & Rebecca Watson. 2024. How Many National Parks Are There? National Park Foundation Accessed January 20, 2024 at: https://www.nationalparks.org/connect/blog/how-many-national-parks-are-there.
[11] World National Parks. National Parks of the World. Accessed January 20, 2024 at: https://worldnationalparks.com/.

(hooved mammals) and two bears (grizzly and black), for a grand total of almost 400 species of vertebrates (**Figures 1-5 and 1-6**).[12]

Figure 1-5. Rocky Mountain Elk
Photo credit: National Park Service

Figure 1-6. Bison grazing in Yellowstone National Park
Photo credit: National Park Service

[12] National Park Service. 2019. Yellowstone Wildlife. Accessed January 21, 2024 at: https://www.nps.gov/yell/learn/nature/wildlife.htm.

Many Native American Tribes in the GYE and beyond to the Great Plains have long enjoyed a special relationship with the American bison (popularly known as the buffalo) in particular, hunting them for many centuries on foot, and later on horseback (**Figure 1-7**), after Spaniards reintroduced the domesticated horse to the Americas in the 1500s. Arapaho, Comanche, Sioux (Lakota), Cheyenne, Blackfoot, Navajo, and Paiute are only the some of the tribes who depended on the bison as a source of food, clothing, tools, shelter, jewelry and in religious ceremonies. The decimation of this iconic grazing ungulate in the 19th century was closely tied to the devastation of these indigenous peoples themselves.[13]

Figure 1-7. "Indian Hunting Buffalo" (no date) by Edward Willard Deming (1860-1942)

The GYE, and in particular Yellowstone NP, played a critical role in averting the extinction of the bison in the American West, as tens of millions were slaughtered in the 1800s. Yellowstone is the only place in the U.S. where free-ranging bison have lived continuously since prehistoric times. The Yellowstone herd is still America's largest bison population on public land. Thousands of buffalo roam relatively freely over the extensive landscape of Yellowstone NP and outside the park in neighboring Montana.[14]

[13] National Park Service. 2023. People and Bison. https://www.nps.gov/subjects/bison/people.htm.
[14] National Park Service. 2024. Bison. Accessed at: https://www.nps.gov/yell/learn/nature/bison.htm.

Figure 1-8. Yellowstone Bison toughing out a Winter Snowstorm
Photo credit: National Park Service

As with Yellowstone NP, the human history of Grand Teton National Park dates back some 11,000 years or more to the appearance of the first Paleo-Indians on the scene. These hunter-gatherers came during warmer months in pursuit of prey and plants useful for their survival. After the passage of many millennia, in the early 1800s, the first Euro-American explorers encountered the Eastern Shoshone in the area. In the first half of the 1800s, trappers and fur traders arrived to exploit and ultimately deplete the area's beaver population. U.S. government expeditions to the region followed exploration of the Yellowstone area just to the north, and the first permanent Euro-American settlers in Jackson Hole arrived in the 1880s (**Figure 1-9**).[15]

The long campaign to preserve the spectacular Teton Range as a national park began in the late 19th century after the establishment of Yellowstone NP in 1872, and in 1929 Grand Teton National Park was established, setting aside only the major peaks of the Tetons. The valley to the south known as Jackson Hole continued in private ownership until the 1930s, when conservationists led by philanthropist John D. Rockefeller Jr. began acquiring land in Jackson Hole to be added to the existing national park. Rockefeller's and conservationists' efforts were very controversial and opposed by local public opinion, but they eventually succeeded, and much of Jackson Hole was set aside for protection as a national monument in 1943, during World War II. In 1950, the monument status was eliminated and most of the acreage was added to Grand Teton National Park.[16]

[15] *Wikipedia*. 2023. Grand Teton National Park. Accessed 1-21-2024 at: https://en.wikipedia.org/wiki/Grand_Teton_National_Park#Ecology.
[16] Ibid.

Figure 1-9. Historic John Moulton Barn on Mormon Row in Grand Teton NP
Photo credit: Jon Sullivan, Wikipedia Commons

The consummate wildlife biologist Olaus Murie (1889-1963) and his conservationist wife Margaret (Mardy) (1902-2003) settled in tiny Moose in the Jackson Hole area in the late 1920s. Murie worked for the U.S. Bureau of Biological Survey, precursor to the U.S. Fish and Wildlife Service,[17] and he was an authority on ungulates such as caribou and elk. He was also an early board member and later president and executive director of the Wilderness Society, and he and Mardy both lobbied hard for the passage of the Wilderness Act in 1964. They co-authored *Wapiti Wilderness* in 1966, which recounted Olaus' research into the Jackson Hole elk herd and their romantic and adventurous life together in the Wyoming wilderness.

Murie had been hired by the National Elk Commission to investigate the cause of the chronic elk winterkill problem at the National Elk Refuge in Jackson Hole. As the chief field biologist, Murie discovered that human development was causing overcrowding in the elk's

[17] U.S. Fish and Wildlife Service. No date. Olaus (1889-1963) and Mardy (1902-2003) Murie. Accessed January 22, 2024 at: https://www.fws.gov/staff-profile/olaus-1889-1963-and-mardy-1902-2003-murie.

winter range, provoking excessive mortality.[18] He was one of the first to realize that this elk herd migrated seasonally between the mountains and the plains. In general, Murie advocated for keeping ecosystems intact when delineating and enacting park boundaries; this would encourage the long-term viability of the ecosystems they aimed to preserve rather than drawing arbitrary or political boundaries.[19] Early ecological insights like these helped give impetus to the emerging fields of landscape ecology, ecosystem management, and the eventual formation of the Greater Yellowstone Ecosystem concept.

Today, nearly half-way through the third decade of the 21st century, the GYE thankfully remains a largely rural and low-population-density ecoregion, which is qualified good news for wildlife, wilderness, and national parks. Two-thirds of the GYE is in Wyoming, the least populous state (584,057 in 2023) of all 50, but Montana has grown to 1.1 million in 2023 from under 700,000 in 1970, and Idaho, now approaching 2 million, has been the fastest-growing state in the country for the past decade.[20] While still relatively small, the population of the 20 GYE counties that are the focus of this study has swollen enormously in recent decades, from just over 300,000 in 1982 to nearly 540,000 in 2022, a jump of 80 percent.[21]

The population of Gallatin County's Bozeman, home to Montana State University, has tripled from 18,760 in 1970 to 58,250 in 2023. It grew by 2.8% in 2022 alone, and in recent years has been the fastest-growing small city in the United States.[22] And GYE wildlife is paying the price of this explosive growth and related sprawl into former rural areas and wildlife habitat (**Figure 10**). Noted Yellowstone Ecosystem author Todd Wilkinson, former editor of *Mountain Journal*, writes about one of the Gallatin Valley's iconic species:

> Just three decades ago, upwards of 2,000 elk, members of the famous Gallatin Herd, could be seen wintering in the Gallatin Valley south of Bozeman. Today, amid scattershot suburban and exurban sprawl, only smaller pockets remain and they are being steadily squeezed by more and more residential subdivision. Besides declining numbers, there has been a corresponding increase in accidents and road-killed elk and deer and even reports, according to a Montana Fish Wildlife and Parks biologist, of rising incidence of [diseases] like hoof-rot….
>
> Need we also say that many of the newcomers building ranchettes are more intolerant of wildlife and will complain to state wildlife managers that wapiti [elk] get into their gardens and eat their shrubs. Sometimes, even, predators will follow elk and deer into subdivisions and those animals are removed.

[18] Ken Zontek. 1998. The Savy of a Sage: Olaus Murie and the Historic Range of Wapiti in the West. *Annals of Wyoming: The Wyoming History Journal*. 70 (4).
[19] National Park Service. 2022. Murie Ranch. Accessed online on January 22, 2024 at: https://www.nps.gov/grte/learn/historyculture/murie.htm.
[20] https://www.populationu.com/gen/us-states-by-population (from U.S. Census Bureau data).
[21] U.S. Census Bureau. County population estimates for 1982 and 2022 for each of the 20 GYE counties at www.census.gov.
[22] Taunya Fagan. 2023. Bozeman Demographics. Accessed online on January 28, 2024 at: https://www.taunyafagan.com/bozeman-demographics/.

> As some say, the proliferation of trophy homes in the Gallatin and other valleys is creating a homeless problem for wildlife being usurped of secure habitat that has existed for millennia. Land fragmentation also makes it more difficult for traditional farmers and ranchers to operate at sustainable economic scale, thus resulting in loss of rural culture which has been an important part of local identity and traditions. Sprawl begets sprawl begets sprawl which creates ever smaller islands of habitat and agricultural land and eventually wildlife and farmers and ranchers disappear.[23]

Figure 1-10. Squeezed out: Wintering elk in the Gallatin Valley are crowded into smaller and smaller patches as they lose ground to sprawling residential development
Photo credit: Holly Pippel

The largest human settlements in the GYE today are Wyoming's Jackson, Pinedale, Cody, and Afton; Idaho's Driggs, Victor, and Idaho Falls; and Montana's West Yellowstone, Red Lodge, and Bozeman. There are many scattered smaller communities as well. Most of the GYE's villages and town are connected to the neighboring public lands and several of them serve as gateways to Yellowstone and Grand Teton national parks. While they display divergent socioeconomic profiles, tourism, outdoor recreation, and the service sector have become increasingly important in all of these communities. At the same time, traditional

[23] Todd Wilkinson. 2024. Personal communication (email) to the senior author. January 27.

large ranches continue to be a significant presence in the GYE.[24] They make important contributions to the rural economy, open space, critical wildlife habitat, and last but not least, to the region's character and reputation, as popularized by the hit television series *Yellowstone*. Set in a present beset with fierce and unrelenting struggles over precious land between ranchers, conservationists, developers, cowboys, Indians, newcomers, and old timers, it pits the Old West against the New West.

Although *Yellowstone* is decidedly fictional – and exceptionally but not unexpectedly (coming from Hollywood) violent, garish, and over-the-top – many of its underlying themes and conflicts do mirror those now unfolding in the contemporary Greater Yellowstone Ecosystem.

1.2 GRIZZLIES, WOLVES, BISON, ELK, PRONGHORN AND OTHER WILD CRITTERS

"…most GYE wildlife populations are in better shape today than thirty years ago."
-- Keiter (2020), op. cit., note 2.

We live in an ever more crowded and beleaguered biosphere, on a planet increasingly dominated by the successes and excesses of our own species, *Homo sapiens*. To cite just one prominent measure of this dominance, ours is a world in which humans and our livestock – a tiny handful of domesticated animal species like cattle, pigs, and sheep – now comprise about 95 percent of the total living weight of all (>6,400 wild species of) mammals on Earth.[25] All 8 billion+ living human beings alive today weigh approximately 390 million tons (Mt) (36% of the total global mammalian biomass), compared to 630 Mt of domestic animals (58%), and just 60 Mt of wild terrestrial and marine mammals (5.5%) (**Figures 1-11 and 1-12**).

For example, the weight of all 500,000 (and rapidly declining) elephants on Earth is 1.3 Mt, or 0.3% of the biomass of all living humans. At an estimated 3 Mt, the aggregate biomass of all 50,000 blue whales, the largest creature to have ever evolved and existed on Earth (including the extinct dinosaurs), is just 0.8% of the weight of all people alive today.[26]

In terms of the roughly 600-million year history of multicellular (Eukaryotic) life on Earth, this extreme imbalance – the hegemony of one species and its vassal species (domesticated animals that exist only to serve us) is a very new phenomenon under the Sun. Some 10,000 years ago, an infinitesimally small fraction of Earth's history of complex, multicellular life, the total weight of wild land vertebrates was 99 times greater than the total weight of all human beings; now it's 32 to 1 the opposite direction (**Figure 1-13**).

[24] Keiter. Op. cit. Footnote 2.
[25] Greenspoon et al. 2023. The global biomass of wild mammals. *Proceedings of the National Academy of Sciences*. Vol. 120. No. 10. Accessed February 4, 2024 at: www.pnas.org/doi/10.1073/pnas.2204892120.
[26] Ibid.

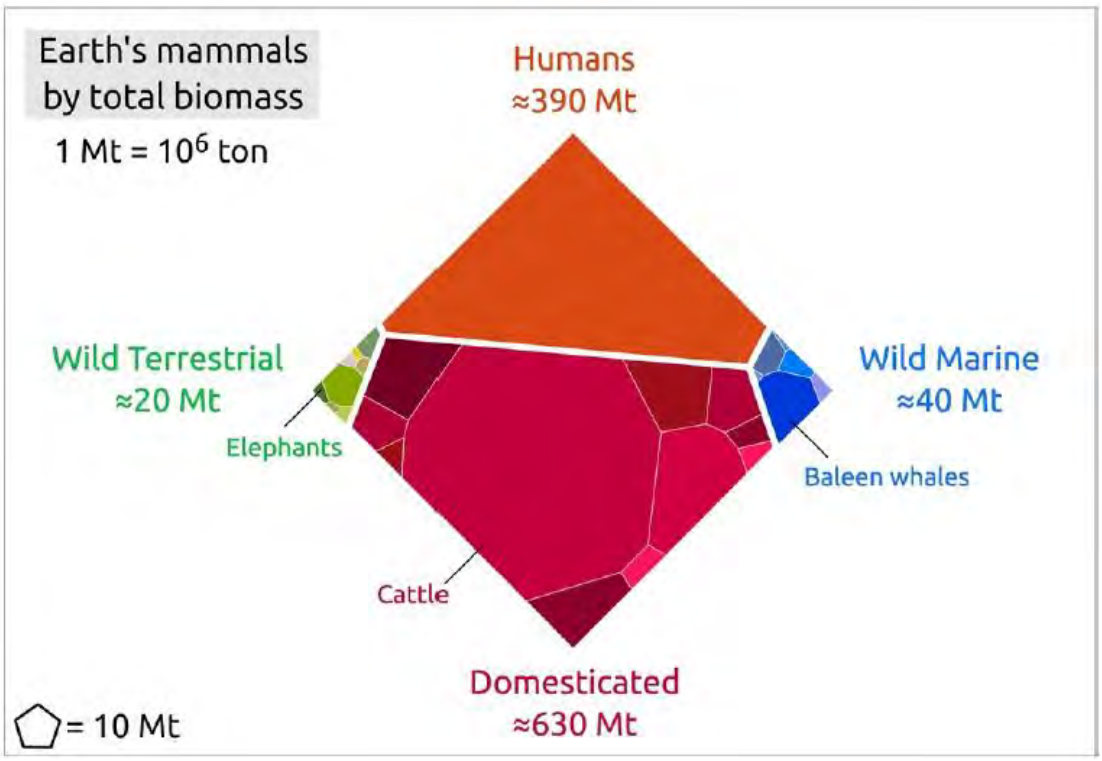

Figure 1-11. Earth's Mammals by Total Biomass
Source: *Proceedings of the National Academy of Sciences*, 2023. Footnote 24

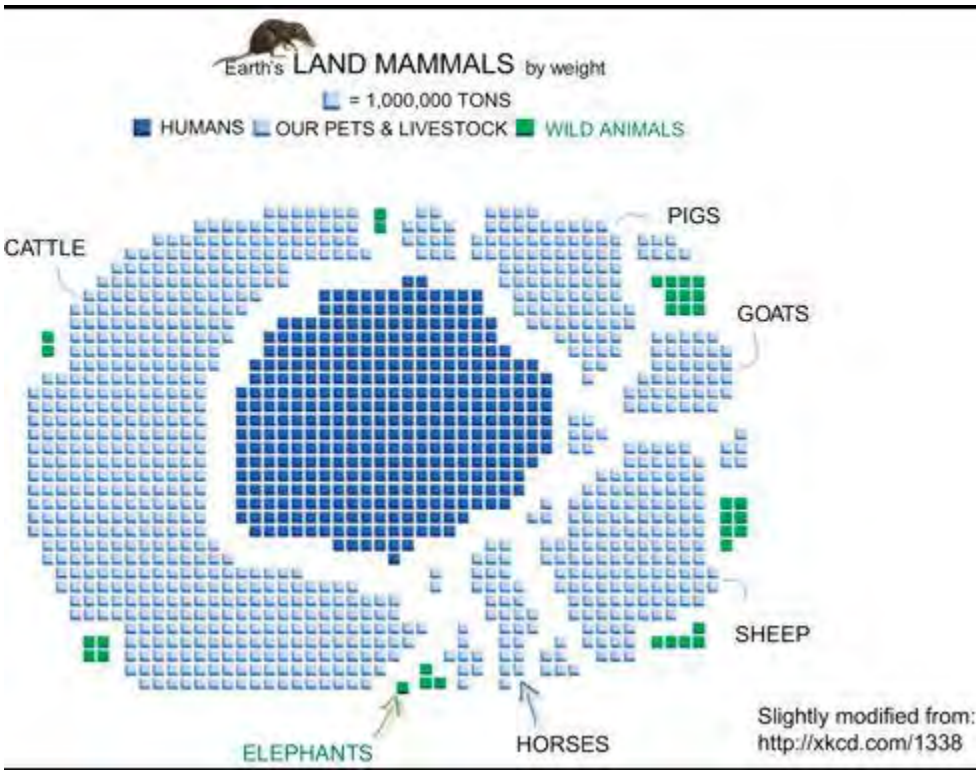

Figure 1-12. Earth's Land Mammals by Weight

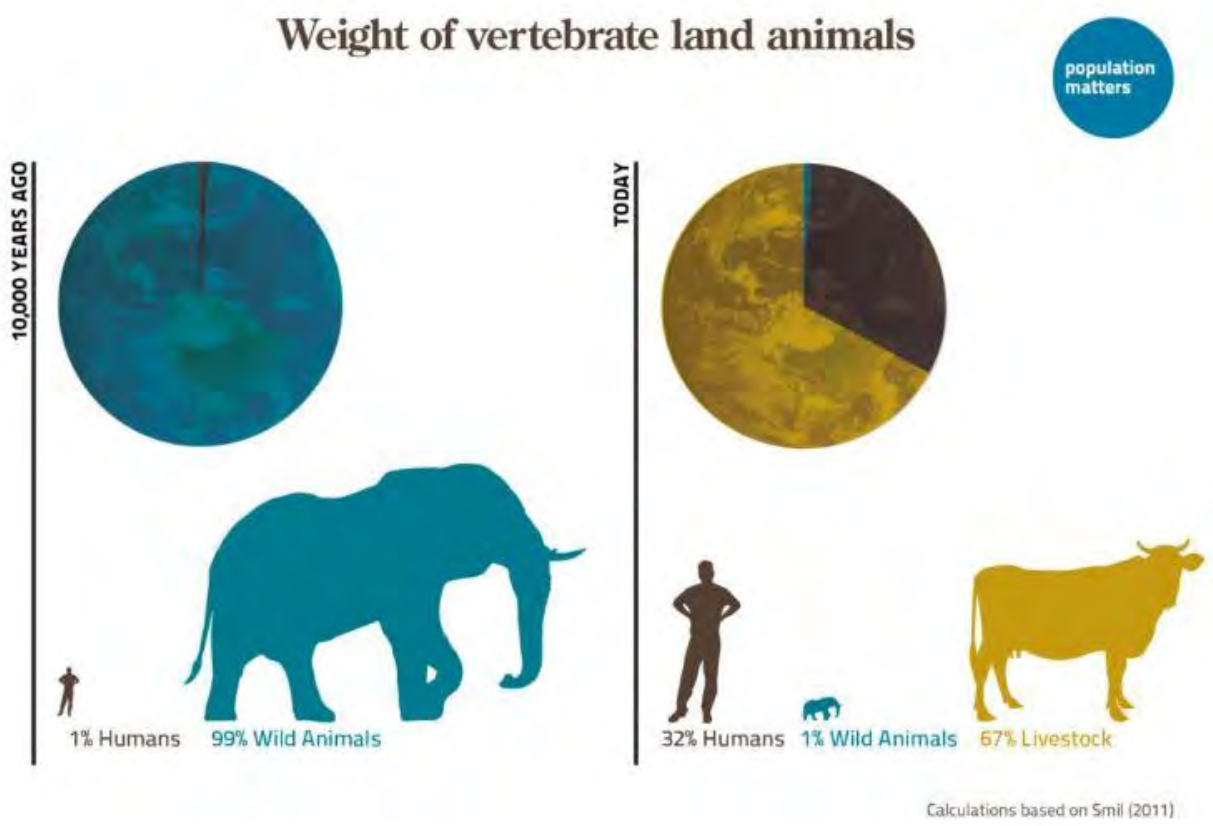

Figure 1-13. Weight of vertebrate land animals 10,000 years ago vs. today

The 2022 Living Planet Index of the World Wildlife Fund (WWF) – which tracks 32,000 monitored populations of vertebrates (mammals, birds, amphibians, fish, reptiles) globally, states that there has been nearly a 70 percent decrease in the overall size of these populations.[27] In North America, the number of wild birds has dwindled by about 30 percent since 1970, a loss of nearly three billion individual birds of many species.[28]

In the context of the above state of spreading biological impoverishment, the Greater Yellowstone Ecosystem is a relative Eden that provides sanctuary to an abundance of "charismatic megafauna." These are the large, shaggy beasts that attract and enthuse visitors, wildlife observers, and armchair adventurers alike, as well as inspiring camera lenses, posters, blog posts, essays, books, legislation, and all too often, controversy.

[27] Living Planet Report 2022. World Wildlife Fund. Accessed February 4, 2022 at: https://livingplanet.panda.org/en-US/#:~:text=The%20Living%20Planet%20Index%20(LPI,analyzed%20almost%2032%2C000%20species%20populations.

[28] Rosenberg et al., 2019. Decline of the North American Avifauna. Science. Vol. 366, No. 6261. Accessed 2-5-2024 at: https://www.science.org/doi/10.1126/science.aaw1313.

We will start with the personal favorite – the grizzly or brown bear – of the senior author, who relished many unforgettable personal experiences at close range with these formidable omnivorous carnivores while working at remote rivers and lakes as a salmon biologist in Alaska.

1.2.1 Grizzly or Brown Bear (*Ursus arctos*)

Two of the three species of bears native to North America inhabit the GYE: the grizzly or brown bear (*Ursus arctos*) (**Figure 1-14**) and the American black bear (*U. americanus*). In this continent, the smaller, generally less aggressive black bear has a much larger range than the grizzly and while its numbers have fluctuated but generally diminished, unlike the grizzly it has never been listed as threatened by the U.S. Fish and Wildlife Service (USFWS).

Figure 1-14. Grizzly bear in Yellowstone National Park
Source: Jim Peaco, National Park Service

The grizzly once inhabited much of the American West, including the Great Plains and the Southwest – even California, where today it survives only on the state flag – but with the relentless spread of Euro-American civilization, it was extirpated (eliminated) from all but a few isolated locations, including the GYE. The Plains grizzly, a now extinct subspecies or race of *U. arctos*, was extant when the Lewis and Clark Expedition paddled and poled up the Missouri River in 1804-1805, and in one of many vivid encounters, on 14 May 1805 a Plains grizzly chased two armed, intrepid members of the Corps of Discovery into the river.

Interestingly, the scientific or Latin name of the grizzly bear was once *Ursus horribilis*, but it was changed to *Ursus arctos* some decades ago in recognition of the circumpolar distribution of this species of bruin. That is, it is found in remote parts of Northern Europe and Siberia as well as North America. Nonetheless, in the interior of North America, including the Northern Rockies and the GYE, the sobriquet "horrible" is still preserved in the subspecies designation for this genetically distinct subspecies of grizzlies, to wit: *Ursus arctos horribilis*.

The GYE, northwestern Montana in the vicinity of Glacier National Park, and the Selkirk Range in the Idaho panhandle are the only areas south of Canada that still possess reasonably large or viable grizzly bear populations. In 1975, the USFWS formally listed the species as "threatened" in the Lower 48 States due to unsustainable levels of habitat loss, fragmentation, and alteration, as well as direct mortality caused by humans. Individual grizzlies have a large "home range"; they can roam across hundreds of square miles in search of food. The ever-present risk of serious or dangerous conflicts with humans -- especially when our food or garbage is a constant temptation for the bears – makes the survival of grizzlies a continuing challenge in the GYE.[29]

Simply put, the grizzly bear and high human population density are incompatible; the "grizz" is a denizen of the wilderness. That is why there are many more grizzly (brown) bears in Alaska (about 30,000), our lowest human population density state by far,[30] than in the rest of the United States combined (about 1,500). This is true even though Alaska, like all northern regions, generally has very low biological productivity, except for its coastal regions, where large salmon runs transport nutrients inland from the fertile North Pacific (fed by nutrient upwellings). The growing human population in the GYE does not bode well for its grizzly bear population.

There are approximately 150–200 grizzly bears with home ranges wholly or partially in Yellowstone National Park, and 1,063 in the GYE as of 2021, a large increase from 136 in 1975. The National Park Service reports that there were 78 "known or probable" grizzly bear mortalities within the GYE in 2021. In contrast, one visitor to Yellowstone NP was injured by a grizzly in 2021, with no human mortalities.[31]

Grizzly bears are on average 1.5 to 2 times larger than black bears (by weight) of the same sex and age class in the same geographic region. In the GYE, males can weigh 200–700

[29] National Park Service. 2023. Yellowstone National Park: Grizzly Bear. Accessed February 10, 2024 at: https://www.nps.gov/yell/learn/nature/grizzlybear.htm.

[30] Alaska's human population density in 2020 was 1.3 residents per square mile, compared to 94.8 for the United States as a whole, 8.6 for Idaho, 7.5 for Montana, and 5.9 for Wyoming. Wyoming is the second least-densely populated state. Alaska ranks 50th, Wyoming 49th, Montana 48th, and Idaho 44th. See: https://en.wikipedia.org/wiki/List_of_states_and_territories_of_the_United_States_by_population_density

[31] Op. cit. Note 28.

pounds and females 200–400 pounds; adults are about 3.5 feet high at the shoulder. Grizzlies have longer, more curved claws (**Figure 1-15**) than black bears; they also have a larger shoulder hump and a more rounded face. They have been known to live up to 30 years in the wild but a more typical life expectancy would be half that. The average male has a home range (area over which they roam in the course of a year in search of food and mates) of 800-2,000 square miles, while females' home range is 300-500 square miles. Grizzlies are fast when they want to be, and have been clocked up to 40 mph. Cubs can climb trees, but their long curved claws and heaviness generally precludes adults from doing so. They are adapted to living in forest, meadows, riparian areas, and tundra. Their diet is omnivorous (including both vegetable matter and meat); they consume grasses, roots, pine nuts (especially those of whitebark pine in the GYE), rodents, insects, elk calves, cutthroat trout, and large mammals. They mate in the spring and give birth to 1-3 cubs during the winter hibernation.

Figure 1-15. Claws of an adult male grizzly bear compared to the hand of a 6-foot man
Photo credit: Leon Kolankiewicz

Environmental law scholar and Yellowstone author Robert B. Keiter writes:

> No animal defines the GYE like the wide-ranging grizzly bear. Indeed, the bear is synonymous with the ecosystem itself and is directly related to regional ecosystem management concepts. Grizzly bear habitat was originally employed to define GYE boundaries, and the federal grizzly bear recovery effort has embraced fundamental ecosystem management strategies. Though protected under the ESA [Endangered Species Act] in 1975, the Yellowstone bear population was still slipping toward extinction during the 1980s, triggering an all-out effort to nurse the bears back to health. Since then, the bear's status as an endangered species has reshaped federal resource management practices and brought federal and state officials together in the recovery effort. A defining

> symbol of the GYE's wildness, the bear also serves today either as the poster child for how the ESA is meant to work or, alternatively, as the imminent victim of a political system unduly dismissive of science and subservient to state and local interests.[32]

In other words, the grizzly bear is both a symbol of enduring wilderness – the very embodiment of Thoreau's saying that "in wildness is the preservation of the world" – and a political football or lightning rod.

1.2.2 Timber or Gray Wolf (*Canis lupus*)

If anything, the gray wolf (**Figure 1-16**) is even more of a contested symbol in the GYE than the grizzly bear. Our ancient ancestors competed with, feared, and fetishized wolves for many hundreds of human generations throughout the Northern Hemisphere. And "man's best friend," the domestic dog (*C. familiaris*), was tamed from wild wolf stock long, long ago. In North America, wolves were once found from the Arctic all the way to Mexico. But widespread habitat loss, destruction of prey, and persecution (extermination programs) by ranchers, governments, and a growing human population generally, extirpated the wolf from almost all of the United States (except Alaska) by the beginning of the 20th century.[33]

Figure 1-16. Gray Wolf in Grand Teton National Park

[32] Op. cit. Note 2.
[33] National Park Service. 2023. Yellowstone National Park: Gray Wolf. Accessed February 11, 2024 at: https://www.nps.gov/yell/learn/nature/wolves.htm.

In 1973, the USFWS listed the northern Rocky Mountain wolf as an endangered species and designated the GYE, from which they had been absent since the 1930s, as one of three recovery areas. Then, in a major milestone of ecosystem restoration, one which attracted global attention, from 1995 to 1997, federal biologists released 41 wild wolves from northwestern Montana and Canada back into Yellowstone NP. Unsurprisingly, as their numbers grew, wolves dispersed from this core population to establish new territories outside the park, where they are more vulnerable to human-caused mortalities, both accidental and deliberate. The National Park Service (NPS), USFWS, and the U.S. Forest Service collaborate to promote the long-term viability of the GYE wolf population, though not always with the eager cooperation of natural resources and wildlife agencies from the three affected states. Overall, Yellowstone wolf restoration has proved a boon to wildlife and ecology researchers, as well as to park and GYE visitors. Researchers, ecologists, and the wolf advocacy community celebrated the 25th anniversary of the Yellowstone wolf reintroduction on January 12, 2020.[34]

Wolves live in extended family units called packs and are very social animals – as is their domestic offshoot, the dog. Among other things, they exhibit cooperative care of pups, cooperation and teamwork in hunting of large prey and defense of prey carcasses. In the GYE, the average pack size consists of about 12 individuals. Each pack has a complex social structure, including an alpha male and female, older and younger members, dominants and subordinates; each wolf possesses its own personality traits and roles within the pack. A pack actively defends its territory from other packs.

The adult gray wolf averages 26-36 inches tall at the shoulder, and 4-6 feet long from snout to tip of tail; it is substantially larger than other canines in the GYE and North America, namely the coyote and fox (**Figure 1-17**). Males weigh 100-130 pounds and females range from 80-110 lbs. Their home range in Yellowstone NP, which varies with pack size, food availability, and season, is 185–310 square miles. Their average lifespan is 4-5 years within Yellowstone NP, and somewhat less outside the park due to higher mortality rates. Whereas bears are omnivores, wolves are primarily carnivores; they kill and eat mainly hoofed mammals, and in Yellowstone NP, 90% of their winter diet is elk; their summer prey is more diverse, including more deer and smaller mammals.[35]

Wolves mate in February and females give birth to average of five pups in April after a gestation period of two months. Pups emerge from their dens at 10–14 days. Tellingly, the main cause of death for wolves within Yellowstone NP is death by other wolves, whereas outside the park, the leading cause of wolf mortality is anthropogenic (human). In general, the number of wolves in Yellowstone NP has fluctuated between 83 and 123 since 2009. As

[34] Ibid.
[35] Ibid.

of January 2023, there were at least 108 wolves in 10 packs in Yellowstone NP alone. These are the core of the larger, interconnected GYE population.[36]

Figure 1-17. Relative sizes of red fox (front), coyote (middle), and timber wolf (back)
Credit: Michael Warner, National Park Service

Wolf behavior is always interesting and sometimes unexpected. For example, in 2000, subordinate females of the Druid pack killed the pack's alpha female and then raised her pups with their own litters. In 2019, a subordinate female of the Junction Butte pack killed the pups of the alpha female, and the rest of the pack then raised the subordinate female's pups.[37]

Wolf restoration to the GYE is an important scientific experiment and a great conservation achievement, one which has resulted in a myriad of interconnected ecological effects, most of them beneficial. For example, other species are direct beneficiaries of wolf predation. When wolves kill an elk, magpies and ravens are on the scene almost at once. Coyotes appear and feed as soon the wolves' hunger is sated. If bears show up, they often try to drive the wolves off, and usually succeed. Many other creatures consume the remains of the carcass.[38] Nothing goes to waste in the great circle of life. Every morsel, every shred, is recycled.

[36] Ibid.
[37] Ibid.
[38] Ibid.

At the same time, wolf restoration has also entailed mostly positive and some negative economic impacts on the local economy. Yet it has sharply aggravated existing social and political tensions between the federal and state governments and the various communities of stakeholders among the public. Keiter notes that increasing wolf numbers led to "flared" passions among rival interests. In the midst of the controversy, the USFWS attempted but failed to return responsibility for wolf management to the three states, blocked by lawsuits from the conservation community. In spite of the ongoing mistrust between conservationists and ranchers, and the lack of cooperation and coordination between state and federal agencies, states now have authority for GYE wolves outside of the two national parks.[39]

The upshot is that wolves, like grizzly bears, are creatures of the untrammeled wilderness. They thrive best in the absence of people, our stuff, and our activities. As of 2020, there were about 7,500 gray wolves in the entire Lower 48 States, a huge increase over their numbers in 1973 when the Endangered Species Act that protects them was passed.[40] In contrast, Alaska supports an estimated 7,000 to 11,000 wolves[41] in a much smaller area than the Lower 48 States, because human numbers and settlements are so much smaller there.

1.2.3 Bison or American Buffalo (*Bison bison*)

As observed in the introduction to this report, the bison is a powerful symbol not just of the GYE, but of the entire American West, as well as the subject of a recent 4-hour PBS documentary by celebrated filmmaker Ken Burns.[42] Its demise (read: orgy of slaughter) and partial recovery from the brink of extinction and oblivion is a gripping story of destruction and redemption that reflects the very worst and best in the American character. In the 1800s, market hunting, wanton slaughter, and the U.S. Army killed tens of millions of bison, nearly annihilating them altogether. By 1902, poachers had decimated Yellowstone's herd and only about two dozen remained. The U.S. Army then redeemed its earlier role as a destroyer of bison, and provided armed protection to save these remaining few in Yellowstone.[43]

According to NPS, in recent years, the number of bison in Yellowstone NP has ranged from about 3,000 to nearly 6,000 (4,830 in the summer of 2023), and includes two primary breeding herds: the northern and the central. For visitors to the national park, they can be observed year-round in the Hayden and Lamar valleys. In the summer, they graze in

[39] Op cit. Note 2.
[40] Tess Joosse. 2021. Wolf Populations Drop as More States Allow Hunting. *Scientific American*. Accessed online on February 12, 2024 at: https://www.scientificamerican.com/article/wolf-populations-drop-as-more-states-allow-hunting.
[41] Alaska Department of Fish and Game. No date. Wolf (*Canis lupus*). Accessed February 12, 2024 at: https://www.adfg.alaska.gov/index.cfm?adfg=wolf.printerfriendly.
[42] Ken Burns. 2024. The American Buffalo, a Film by Ken Burns. Accessed online on February 16, 2024 at: https://www.pbs.org/kenburns/the-american-buffalo/.
[43] Op. cit. Note #13.

grasslands, and in the winter, they can be found in the park's hydrothermal areas, Madison Valley, Blacktail Deer Plateau, Tower, and the Gardiner Basin.[44]

Male bison (called bulls) can weigh up to 2,000 pounds (a ton) (**Figure 1-18**), while females (cows) reach half that weight, topping out at about a thousand pounds (half a ton). The species can live some 12-15 years in the wild, with a few attaining 20 years of age. They are grazers, eating mostly native grasses and sedges. Bison mate in the summer, and females give birth to one calf the following spring. The American buffalo is agile, potentially aggressive (if feeling threatened), and can reach speeds of 30 mph.[45]

Figure 1-18. Adult Male Bison

Everyone agrees that rescuing the American buffalo from extinction is a magnificent victory for wildlife conservation. Yet because of competing interests for shrinking room and resources (a fixed and falling quantity of open space), managing the Yellowstone bison herd has proved to be a highly controversial endeavor – like so much wildlife management in the GYE has become. One reason is that the Yellowstone bison herd is naturally prone to migrate to different habitats with the seasons, including out of the park and across other jurisdictional boundaries, into increasingly congested landscapes off federal lands in the GYE (**Figure 1-19**).

Another complication is the disease called brucellosis. This is a bacterial infection that can afflict both bison and cattle. While brucellosis does not kill afflicted individuals, it can

[44] Op. cit. Note #13.
[45] Op. cit. Note #13.

nevertheless induce abortions or stillbirths. This in turn could have an adverse economic impact on ranchers because it would negatively affect both the reproductive rate and marketability of their livestock. While brucellosis has been largely eradicated in cattle herds across the U.S., bison and elk in the GYE are one of the persistent "reservoirs of infection" remaining in the country. Ironically, it was domestic cattle that first introduced brucellosis to GYE bison and elk in the early 1900s. Today, up to 60 percent of Yellowstone bison (depending on age and sex) test positive for exposure to it. Vaccinating them against it has proved to be impractical and ineffective, as concluded by a detailed investigation carried out in a 2014 Environmental Impact Statement (EIS) prepared by NPS.[46] Thus the livestock industry and the states are adamantly opposed to allowing migrating wild bison or their expanding numbers to mingle with cattle on lands outside of Yellowstone NP. This places an effective cap on the number of bison that the available range can accommodate.

Figure 1-19. "Bison from Yellowstone don't have enough room to roam outside the park" – National Park Service

The Interagency Bison Management Plan, which resulted from a court-mediated settlement, established a cooperative effort in 2000 of eight federal and state agencies and tribal nations to manage GYE bison. As stated by NPS:

> Because Montana law limits the areas bison can move outside the park, and because bison outside the park are valued by state and Tribal hunters and

[46] National Park Service. 2024. Yellowstone National Park: Bison Management. Accessed February 17, 2024 at: https://www.nps.gov/yell/learn/management/bison-management.htm#questions_answers; National Park Service. 2014. *Final EIS for Remote Vaccination Program to Reduce the Prevalence of Brucellosis in Yellowstone Bison*. Accessed February 17, 2024 at: https://parkplanning.nps.gov/document.cfm?parkID=111&projectID=10736&documentID=57039.

> others, managing bison is a balancing act between having enough bison to support a healthy population and some migrations out of [Yellowstone National] park, but not too large a population that could lead to mass migrations and cause brucellosis transmission to livestock, harm people, or damage private property. Currently, the park's bison population is managed through three main ways: (1) Tribal hunts and state hunts outside Yellowstone's boundary; (2) capture and transfer to Tribes for shipment to slaughter; and (3) capture for brucellosis testing and transfer to Tribes to start their own bison herds.[47]

Since 2019, more than 400 bison have been transferred to 26 American Indian Tribes around the United States (**Figure 1-20**).[48]

Figure 1-20. Opening prayer by Leroy Stewart, Bison Project Director, Crow Nation, at the Bison Conservation Transfer Facility Expansion Commemoration in 2023
Source: Jacob W. Frank, NPS

[47] Ibid. NPS 2024. Yellowstone National Park: Bison Management.
[48] Ibid.

1.2.4 Elk or Wapiti (*Cervus canadensis*)

The Rocky Mountain elk (**Figure 1-21**) is the single most abundant large mammal in Yellowstone NP as well as a key species of the GYE as a whole. In the summer, some 10,000 to 20,000 elk in half a dozen different herds frequent the park. Their numbers drop to under 4,000 in the winter, when elk migrate north out of the park to toward Gardiner and the Gallatin Valley in Montana; elk in the southern area migrate south to the Jackson Hole Elk Refuge in Jackson, Wyoming.[49]

Figure 1-21. Bull Elk in rutting (mating) season along the Madison River

Euro-American settlers used the word "elk" to describe this ungulate, which is also the name in Europe for what Americans call "moose." The Shawnee Indian word *wapiti* – meaning "white deer" or "white-rumped deer" – is an indigenous name for elk. In an ongoing taxonomic debate, some authorities regard the North American or Rocky Mountain elk to be the same species as the red deer of Europe (*Cervus elaphus*), but most scientists refer to elk in North America as *C. canadensis*.[50]

With their enormous antlers, bull elk are one of the most photogenic animals in the GYE. As with deer, male elk regrow their antlers annually; at first, they are covered with a thick, fuzzy coating of skin known as "velvet." In early August, antlers stop growing and the bull begins

[49] National Park Service. 2023. Yellowstone National Park: Elk. Available at: https://www.nps.gov/yell/learn/nature/elk.htm.
[50] Ibid.

to scrape off the velvet, polishing and sharpening his antlers.[51] Another characteristic that bull elk are justly famous for is their "bugling" during the rut or breeding season in the fall. This treasured "call of the wild" gives the human listener a powerful sense of time (the autumn season with its crisp nights and brilliant colors) and place (Rocky Mountains).

Bulls (males) weigh about 700 pounds and can stand five feet high at the shoulder, while females (cows) typically weigh 500 pounds and are somewhat shorter than the males. Elk feed on sedges, grasses, other herbs, forbs, and shrubs, the bark of trees (especially aspens), conifer needles, and some aquatic plants.[52]

As the GYE's most plentiful ungulate, elk represent about 85 percent of winter wolf kills. They are also an important food item for mountain lions, bears and at least a dozen species of mammalian and avian scavengers. Elk herbivory (i.e., feeding on plants, or browsing in the case of elk) can affect vegetation distribution, abundance, and diversity. Thus, temporal and spatial changes in elk population size can heavily influence plant and animal communities in the GYE.[53]

As mentioned above, elk, like other large mammals, are getting squeezed by accelerating human population growth and corresponding development in the GYE (**Figure 1-22**). They are confronted with habitat loss as well as increasing direct mortality from such causes as traffic collisions (**Figure 1-23**) as regional vehicular traffic grows along with human numbers.

Figure 1-22. Elk attempt a dangerous road crossing in the Wyoming portion of GYE
Photo credit: Holly Pippel

[51] Ibid.
[52] Ibid.
[53] Ibid.

Figure 1-23. Elk run down and killed by SUV
Photo credit: Holly Pippel

The GYE supports some 30,000-40,000 elk overall. As with bison, elk management is a delicate balancing act. It is complicated by elk migration, wolf reintroduction, increasing human population and development, competing and often at-odds interest groups and federal versus state agencies and jurisdictions, brucellosis (described above under bison), and the ominous risk posed by another disease: Chronic Wasting Disease (CWD). CWD is caused by naturally-occurring but misshapen proteins called prions. It is an infectious, degenerative disease of cervids (e.g., elk, deer, and moose) that kills brain cells, eventually killing the inflected animal itself. There is no known cure. It is similar to "mad cow disease" in cattle, scrapie in sheep, and Creutzfeldt-Jacob Disease (CJD) in humans, all caused by prions.[54]

[54] U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS). 2023. Cervids: Chronic Wasting Disease. Accessed February 18, 2024 at: https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/animal-disease-information/cervid/cervids-cwd/cervid-cwd#:~:text=Chronic%20Wasting%20Disease%20(CWD)%20is,death%20of%20the%20affected%20animal.

No public elk hunting is permitted on the two national parks in the GYE, but it does occur intensively on national forest and private lands, and elk hunters are yet another force to be reckoned with by wildlife managers.

Elk that are artificially fed in the winter exhibit high levels of brucellosis infection because of their high densities. While winter feeding on the northern range in the GYE ceased more than half a century ago, elk are still fed during the winter at the National Elk Refuge in Jackson, Wyoming and nearly two dozen other feeding grounds in the state. These artificial sources of winter food were begun in the last century to prop up Wyoming's elk herds and limit depredation by elk as their migratory routes from their higher-elevation summer range to their lower elevation winter range were increasingly obstructed by population growth and development in the Jackson area. Feed ground elk, where about 30 percent have tested positive for exposure to brucellosis, were the apparent source of transmission of the bacteria to Wyoming cattle in 2004.[55]

1.2.5 Pronghorn (*Antilocapra americana*)

The North American pronghorn (**Figure 1-24**), renowned for its swiftness, is the only surviving species of a family of hooved mammals that first appeared in North America some 20 million years ago. Pronghorns can reach speeds of 45-50 mph, an adaptation evolved to outsprint an extinct species of North American cheetah, *Miracinonyx*. The pronghorn is often dubbed an antelope, but is not a true antelope, which occurs in Africa and Southeast Asia. Misnaming them "antelope" seems to have started during the 1804–1806 Lewis and Clark Expedition.[56]

Figure 1-24. Adult Male (Buck) Pronghorn
Source: Neal Herbert, National Park Service

[55] Ibid.
[56] National Park Service. 2023. Yellowstone National Park: Pronghorn. Accessed February 18, 2024 at: https://www.nps.gov/yell/learn/nature/pronghorn.htm.

Before Euro-Americans colonized the West, an estimated 35 million pronghorns roamed the Great Plains and Rocky Mountain foothills in the United States and Canada, not quite as many pronghorns as bison, but huge numbers nevertheless. Then, rapid human population growth, development and displacement, habitat conversion (from rangeland and prairie to cropland), and uncontrolled hunting drastically reduced their range and numbers. They were killed off by market hunters who sold their meat to city-slickers, and by ranchers convinced that pronghorns competed with livestock for forage. Their herds were decimated.[57]

By the 1920s, only about 31,000 pronghorn survived in North America – less than one in every thousand that had previously existed! – and these pitiful remnants were scattered among small and isolated populations. Then the conservation movement came belatedly to the rescue. Federal and state agencies and non-governmental conservation groups redoubled their efforts to protect the pronghorn from overhunting and their habitats from overgrazing by cattle and sheep. National wildlife refuges were established, and funds allocated from an excise tax on hunting rifles, sporting gear, and ammunition. In a move called "translocation," federal and state agencies also captured and relocated more than 30,000 pronghorn from well-stocked areas to restore or rebuild other decimated populations. These measures proved successful, contributing to gradual growth in pronghorn numbers to greater than one million by the 1980s. Approximately 50 to 60 percent of these live in Wyoming and 20 percent in Montana. Wildlife agencies now implement sustainable harvests in most states.[58]

GYE pronghorn numbers today are but a remnant of a once massive population that used to move en masse back and forth along the valley of the Yellowstone River. Every autumn, mobile and nimble pronghorn would migrate to the exposed, high plains that are now crossed by Interstate 90. Every spring, in turn, they would move back upstream along the Yellowstone to graze in the moist, high-elevation meadows within what is now the national park. Female pronghorns converted nutritional meadow grasses into milk to nurse their fawns (**Figure 1-25**).[59]

Male pronghorns (bucks) typically weigh 100-125 bounds and females (does) about 90 to 110 pounds. They stand 35 to 40 inches tall at the shoulder. Their live 7-10 years in the wild. As noted, they inhabit grasslands, rangeland, and shortgrass prairies, where they eat sagebrush and other shrubs, some grasses, and forbs. Both sexes have horns, but the males' are larger and pronged.[60]

In sum, we can conclude the recent story of the pronghorn is one of qualified success.

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[57] Ibid.
[58] P.J. White, Kerey K. Barnowe-Meyer, Robert A. Garrott, and John A. Beyers. No date. *Yellowstone Pronghorn: Recovering from the brink of extirpation*. 100 pp.
[59] John A. Beyers. No date. Preface to P.J. White et al., *Yellowstone Pronghorn*. Beyers is Professor Emeritus of Zoology, University of Idaho.
[60] Op. cit. Note #55.

Figure 1-25. Mother pronghorn and fawn near Slough Creek in Yellowstone NP
Source: Jacob W. Frank, National Park Service

1.2.6 Other Wild Critters in the Greater Yellowstone Ecosystem

The GYE is also home to hundreds of other species of wild vertebrates (animals with backbones) – mammals, birds, reptiles, amphibians, and fish. As noted earlier, Yellowstone NP alone boasts 67 species of mammals, almost 300 species of birds (some of which are transient migrants), 16 fish, five amphibians, and six reptiles.

Mammals

Mammals range across several orders of magnitude in size, from the little brown bat (*Myotis lucifugus*), weighing in at 0.29 ounce, to the massive moose (*Alces alces*) (**Figure 1-26**) tipping the scales at half a ton. The **moose** is the largest member of the deer family, although GYE moose (*Alces alces shirasi*) are the smallest of four subspecies of moose in North America. Males (bulls) can reach nearly a thousand pounds and females (cows) 900 lbs. Their preferred habitat is wetlands and wet areas, such as ponds, marshy meadows, lakeshores, riparian areas, and riverbanks. Here they browse on the leaves and twigs of willow and other woody species, as well as dining on non-woody aquatic vegetation such as water lilies, duckweed, and burweed. In the winter, moose show a preference for subalpine fir. An adult moose ingests about 10-12 pounds of food per day in the winter and several times that in the summer. The moose population of Yellowstone NP proper – estimated at just 200 – has fallen in the last four decades because of the loss of old growth forests in the GYE, hunting outside the national park, wildfires, and increasing predation.[61]

[61] National Park Service. 2023. Yellowstone National Park: Moose. Accessed February 22, 2024 at: https://www.nps.gov/yell/learn/nature/moose.htm .

Figure 1-26. Bull moose sparring in the fall at Grand Teton National Park
Source: National Park Service

Another large ungulate of the GYE, one a bit more graceful in appearance than the ungainly moose, is the **bighorn sheep** (*Ovis canadensis*) (**Figure 1-27**). Though widely dispersed across the Rockies, these denizens of the mountains are typically found in small, discontinuous populations that are particularly susceptible to abrupt decline or disappearance from disease, habitat loss, or interference with their migratory routes due to roads, traffic, and other forms of human encroachment. Between 10 and 13 interbreeding bands of bighorn sheep occupy rugged areas in the upper Yellowstone River basin, including habitat that reaches more than 20 miles north of the park into Montana, an estimated 345 sheep altogether in 2018 They feed primarily on grasses in the summer, foraging on woody shrubs in the fall and winter.[62]

As shown in **Figure 1-27**, all adult bighorn sheep have horns (not antlers), though the males' are much larger and more curved. Rams' horns can weigh up to 40 pounds – more than 10 percent of its overall weight – on an animal reaching 320 pounds. Ewes weigh about half as much as rams. Mating season begins in November and is marked by fighting and head-on collision between charging rams to establish a dominance hierarchy and access to ewes. As an adaptation to protect the brain from the bone-crushing impact of such clashes, ram skulls have two layers of bone that function as a shock absorber.[63]

[62] National Park Service. 2021. Yellowstone National Park: Bighorn Sheep. Accessed February 23, 2024 at: https://www.nps.gov/yell/learn/nature/bighorn-sheep.htm.
[63] Ibid.

Figure 1-27. Male (Ram, left)) and Female (Ewe, right) Bighorn Sheep

Another charismatic mountain dweller found in the GYE is the **mountain goat** (*Oreamnos americanus*) (**Figure 1-28**), a true specialist of alpine habitats and steep slopes that the senior author of this study remembers fondly from his years exploring the rugged ranges of British Columbia and Alaska to the northwest. Some 200-300 mountain goats are estimated to be present in the GYE.

Figure 1-28. Nanny mountain goat with her kid on Sepulcher Mountain
Source: Diane Renkin, National Park Service

Yet while the mountain goat is native to North America in general, and areas to the north and west in the Northern Rockies in particular, wildlife biologists regard them as a non-native, exotic, or invasive species in the GYE per se (as they are on the Olympic Peninsula of Washington), because they were not present historically, and are newcomers to this ecosystem. Mountains goats colonized the GYE only in the 1990s, and are the descendants of goats introduced artificially by humans in the 1940s and 1950s into the Madison Range to the west and the Absaroka Range to the southeast. Ecologists and wildlife managers worry about the potential adverse effects of mountain goat colonization on fragile alpine habitat and interaction and competition with native bighorn sheep.[64] The National Park Service observes:

> Many people consider the goats a charismatic component of the ecosystem, including those who value the challenge of hunting them outside the park. But the colonization has raised concerns about the goats' effects on alpine habitats. Competition with high densities of mountain goats could also negatively affect bighorn sheep, whose range overlaps that of mountain goats.[65]

The mule deer (*Odocoileus hemionus*) and the white-tailed deer (*O. virginianus*) are two other ungulates found in the GYE. We will not linger on them here because they are so widespread and abundant elsewhere. Suffice it to say that the estimated 45 million white-tailed deer – overpopulated and overabundant (exceeding carrying capacity) in much of its North American range – actually have by far the greatest aggregate living weight or biomass of any of the more than 6,000 wild mammal species that still exist on Planet Earth.[66]

Above we described the grizzly bear and timber wolf, the two most celebrated and controversial members of the taxonomic order Carnivora in the GYE, but many other less prominent but no less important carnivores find a home here as well, such as the **black bear** (*Ursus americanus*), **bobcat** (*Lynx rufus*)**, Canada lynx** (*L. canadensis*), **cougar** (*Puma concolor*, whose other common names include puma and mountain lion), **coyote** (*Canis latrans*) (**Figure 1-29**), **red fox** (*Vulpes vulpes*), and six members of the weasel family (Mustelidae) – **long-tailed weasel** (*Mustela frenata*), **short-tailed weasel** (*M. erminea*) (**Figure 1-30**), **marten** (*Martes americana*), **river otter** (*Lontra canadensis*), **badger** (*Taxidea taxus*), and **wolverine** (*Gulo gulo*).[67]

[64] George Heinz. No date. Mountain Goats in Yellowstone. 6-minute video. Viewed February 2, 2024.
[65] National Park Service. 2021. Yellowstone National Park: Mountain Goat. Accessed February 24, 2024 at: https://www.nps.gov/yell/learn/nature/mountain-goat.htm.
[66] Op. cit. Note #24.
[67] National Park Service. 2023. Yellowstone National Park: Mammals. Accessed February 25, 2024 at: https://www.nps.gov/yell/learn/nature/mammals.htm.

Figure 1-29. Coyote pouncing on prey in Grand Teton National Park
Source: National Park Service

Figure 1-30. Short-tailed weasel on the prowl
Source: Jacob W. Frank, National Park Service

The GYE boasts eight species of rodents, all of which play vital ecological roles in the food chain, web, or pyramid – three metaphors often used to conceptualize the flows or pathways of chemical energy through the sequential levels of ecosystems. Rodents help comprise one arc on what is also metaphorically referred to as the "Great Circle of Life."

As primary consumers or heterotrophs (organisms, mostly animals, unable to produce their own food), rodents consume primary producers, which are also called autotrophs. These are green plants whose chloroplasts are able to manufacture organic matter from solar energy via the incredibly complex (so much so that it sometimes seems like magic) process of photosynthesis. That is, using oxygen, water, and minerals, autotrophs (green plants) convert the incoming photons of solar radiation via the so-called "light reaction" and "dark reaction" of photosynthesis into covalent chemical bonds and organic compounds, starting with the simplest sugar, glucose ($C_6H_{12}O_6$). Rodents eat these plants and their components or products (e.g., buds, berries, fruits, seeds, bark, roots), and in turn are eaten by (provide food to) secondary consumers or carnivores. The GYE's rodents include the **beaver** (*Castor canadensis*), **golden-mantled ground squirrel** (*Callospermophilus lateralis*), **least chipmunk** (*Tamias minimus*), **montane vole** (*Microtus montanus*), **pocket gopher** (*Thomomys talpoides*), **red squirrel** (*Tamiasciurus hudsonicus*), **Uinta ground squirrel** (*Spermophilus armatus*) (**Figure 1-31**), and **yellow-bellied marmot** (*Marmota flaviventris*).[68]

Figure 1-31. Uinta Ground Squirrel
Source: National Park Service

[68] Ibid.

Three species of lagomorphs (i.e., in the taxonomic order Lagomorpha, including rabbits and hares) are found in the GYE: the **American pika** (*Ochotona princeps*) (**Figure 1-32**), **snowshoe hare** (*Lepus americanus*), and **white-tailed jackrabbit** (*L. townsendii*). Of these, the pika has received particular attention in recent years because of the climate change issue; this petite lagomorph is considered an indicator species of the ecological impacts of a warming world. While still abundant in the GYE, the number of pikas is decreasing in lower elevation areas as a result of higher temperatures. These reduce their suitable habitat. While a recent USFWS review of the pika declined to recommend protecting the species under the Endangered Species Act, in coming years it is likely that pikas will disappear from lower elevation or warmer sites within the GYE. In sum, pikas are susceptible to climate change-related habitat loss.[69]

Figure 1-32. American Pika in the GYE
Source: Janine Waller, National Park Service

At present, the cute pika – about the size of a guinea pig – can still be found on talus slopes and rock falls at nearly all elevations throughout much of the GYE. As avid herbivores, they devour vegetation such as sedges, grasses, lichen, aspen, and conifer twigs. In late summer, pika gather mouthfuls of plant matter to build and vigorously defend "haystacks" as winter food caches. These haystacks are often erected in the same spot from year to year and can reach three feet in diameter. Pika predators include coyotes, martens, and hawks.[70]

[69] National Park Service. 2020. Yellowstone National Park: Pika. Accessed February 26, 2024 at: https://www.nps.gov/yell/learn/nature/pika.htm.
[70] Ibid.

Last but not least among the mammals that inhabit the GYE are 13 species of bats (Order Chiroptera). Bats are the only extant mammals on Earth whose ancient ancestors evolved wings and the marvelous power of "sustained, flapping flight" (as opposed to gliding), entirely independently of birds evolving those same capabilities deep in the evolutionary past. NPS conducts bat monitoring efforts in Yellowstone National Park using acoustic surveys and mist-net capture and these have identified the following species:

- **Little brown bat** (*Myotis lucifugus*) (**Figure 1-33**)
- **Big brown bat** (*Eptesicus fuscus*)
- **Long-eared myotis** (*M. evotis*)
- **Long-legged myotis** (*M. volans*)
- **Townsend's big-eared bat** (*Corynorhinus townsendii*)
- **Fringe-tailed bat** (*M. thysanodes*)
- **Hoary bat** (*Lasiurus cinereus*)
- **Silver-haired bat** (*Lasionycteris noctivagans*)
- **Spotted Bat** (*Euderma maculatum*)
- **Pallid Bat** (*Antrozous pallidus*)
- **California Myotis** (*M. californicus*)
- **Western-Small-footed Myotis** (*M. ciliolabrum*)
- **Yuma myotis** (*M. yumanensis*)[71]

Figure 1-33. Pair of little brown bats hanging out together
Source: John and Karen Hollingsworth, U.S. Fish and Wildlife Service

[71] National Park Service. 2020. Yellowstone National Park: Bats. Accessed February 27, 2024 at: https://www.nps.gov/yell/learn/nature/bats.htm.

Bats use echolocation to fly, navigate, and locate food – primarily flying insects – in the dark. They emit pulses of high-frequency ultrasonic sound (beyond the human hearing range) and detect the returning echoes, with provide them with a sonic image of their surrounding environment, including movements of their prey. Most bats also use lower-frequency sounds (often within our hearing range) to communicate with each other. When resting, bats roost head down, which makes them less vulnerable to predators and enables ready flight. When hibernating, they can remain upside down for months at a time.

The devastating disease outbreak known as white-nose syndrome (WNS) has not yet arrived in the GYE. WNS is caused by the exotic (non-native or introduced) fungal pathogen *Pseudogymnoascus destructans*, and has led to population collapses as high as 99 percent among wintering bats of various species, even regional extirpation or extinctions of several species in northeastern North America.[72]

Birds

Almost 300 avian species have been documented in Yellowstone NP, and of these, about 150 breed there, i.e., mate, build nests, lay and incubate eggs, hatch and fledge their offspring. Raptors (eagles, hawks, and owls), songbirds, shorebirds, and waterfowl are all found, but no federally threatened or endangered birds, although the golden eagle, trumpeter swan (**Figure 1-34**), and common loon are considered "species of concern." The wide variation in elevations and diverse habitat types contribute to the relatively high species diversity.[73]

Figure 1-34. Family of Trumpeter Swans
Source: Amanda Boyd, National Park Service

[72] Ibid.
[73] National Park Service. Yellowstone National Park: Birds. Accessed February 29, 2024 at: https://www.nps.gov/yell/learn/nature/birds.htm.

Every June since 1980, during the peak of songbird mating season, Yellowstone NP has participated in breeding bird surveys. These are a continent-wide, long-term monitoring effort coordinated between the Biological Resources Division of the U.S. Geological Survey, the Canadian Wildlife Service's Research Center, and Mexico's National Commission for the Knowledge and Use of Biodiversity. In Yellowstone, the breeding bird surveys are road-based, with qualified observers noting all birds seen and heard within a quarter mile radius.[74]

It is only through a long-term commitment to baseline monitoring from dedicated surveys and programs like these that ornithologists and wildlife biologists can state with any authority, assurance, and accuracy what the long-term trends in bird populations actually are on a continental scale. And what the monitoring reveals about these trends is troubling. As noted above, a 2019 paper in the journal *Science* indicated that the total number of birds in North America has declined by about 30 percent since 1970, or a loss of almost three billion individual birds. The number of breeding birds in the United States and Canada was estimated at 10 billion in 1970. By 2019, that number had dropped to approximately 7.1 billion.[75] Safeguarding the integrity of wildlands like the GYE is critical to the survival and health of beleaguered North American bird populations and to halting and reversing this grim trend.

Yellowstone NP is home to 19 species of breeding raptors, including bald and golden eagles, peregrine falcons, and ospreys, as well as the smaller American kestrel, and Swainson's hawk. Among the owls found in the GYE are the great-horned, great grey (**Figure 1-35**), saw-whet, and northern pygmy. The great gray owl (*Strix nebulosa*) is a northern species that spans both hemispheres; it is the world's largest owl by length (almost three feet) and has a wingspan that can surpass five feet.

Figure 1-35. Great Gray Owl
Source: National Park Service

[74] Ibid.
[75] Op cit. Note 27. Rosenberg et al. 2019. Decline of the North American avifauna. *Science*. Vol. 366, No. 6461. Available online at: https://www.science.org/doi/10.1126/science.aaw1313.

Almost a third of Yellowstone's breeding bird species depend on wetlands and waters. Among these are the colony-nesting birds – which build their nests in large groups – such as the white pelican (*Pelecanus erythrorhynchos*), California gull (*Larus californicus*), Caspian tern (*Hydroprogne caspia*), and double-crested cormorant (*Phalacrocorax auritus*). Many of these are concentrated in the Molly Islands of the southeast arm of Yellowstone Lake. Populations of these colonial nesting birds have declined over the past two decade, for reasons that are not entirely clear. One may be the corresponding decline in the native cutthroat trout population (discussed below), a known food source for these birds.[76]

The majority of breeding bird species in the GYE (and elsewhere) are songbirds (**Figure 1-36**) and woodpeckers, that is, passerine (perching) and near-passerine species. These are found in diverse habitats throughout the Greater Yellowstone Ecosystem: riparian forests like stands of willow, recently burned forests, old-growth forests, grasslands, and sagebrush steppe.

Figure 1-36. Mountain Chickadee (*Poecile gambeli*)
Source: National Park Service

Starting in the early 1900s, woody riparian vegetation and willows in particular in the northern portions of the GYE were stunted or suppressed by herbivory (browsing by elk), reduced beaver populations, and wildfire. Along with the reintroduction and recovery of several large predator species in the park (such as the wolf), some of these willow stands have grown denser in the past three decades, resulting in a range of conditions favorable to birds such as Wilson's warbler (*Cardellina pusilla*), willow flycatcher (*Empidonax traillii*), and gray catbird (*Dumetella carolinensis*), which breed only in willow-dominated habitat. Altogether, biologists have documented 39 songbird species in GYE willow habitats, with species diversity greater among taller rather than smaller (suppressed) willows.[77]

[76] Op cit. Note #72.
[77] Op cit. Note #72.

Songbirds also abound in the mature forests of the GYE, which under the hotter and drier climatic regime expected in the future may be subjected to more frequent and/or severe fires. Such ecological disturbances could disproportionately affect stands of mature forest, which, by definition, take longer to recover after large burns. In 2021, ornithologists recorded 21 species in the mature forests of Yellowstone NP, the most numerous of which were pine siskin (*Spinus pinus*), mountain chickadee (*Poecile gambeli*), American robin (*Turdus migratorius*), ruby-crowned kinglet (*Regulus calendula*), yellow-rumped warbler (*Setophaga coronata*), and dark-eyed junco (*Junco hyemalis*). Species diversity increased with forest complexity, from 11 passerine species in lodgepole pine-dominated and mixed lodgepole-spruce forests to 18 species in Douglas fir and spruce forest.

Our brief discussion of birds in the GYE would be incomplete without a mention of one of the senior author's and Edgar Allen Poe's favorite and most intriguing avian species: the common raven (*Corvus corax*) (**Figure 1-37**). Ravens are in the family Corvidae, along with their cousins the American crow, four species of jay, Clark's nutcracker, and the black-billed magpie. Ravens are widely acknowledged as among the smartest of all birds, and creative ethologists (scientists who study animal behavior) continue to devise new ways to test their cognitive abilities and problem-solving. As the Cornell Lab of Ornithology puts it: "These big, sooty birds thrive among humans and in the back of beyond, stretching across the sky on easy, flowing wingbeats and filling the empty spaces with an echoing croak."[78]

Figure 1-37. Common ravens: abundant and intelligent denizens of the GYE
Source: Neal Herbert, National Park Service

[78] Cornell Lab of Ornithology. 2024. All About Birds: Common Raven. Accessed online March 2, 2024 at: https://www.allaboutbirds.org/guide/Common_Raven/overview.

Ravens may follow wolves as they hunt elk and are known scavenge at wolf kills. By ripping open carrion with their powerful teeth and jaws, wolves provide access to meat for scavengers like the raven, which is unable to penetrate thick skin and fur with its beak. Ravens, like crows, are adaptable omnivores and able to eat just about anything; they are tempted by the abundant food found around humans, our parking lots, and garbage cans. It is estimated that before wolf reintroduction in the mid-nineties, about three-quarters of ravens in Yellowstone NP likely frequented human areas and depended on human sources of food.[79]

Reptiles

Six species of reptiles are confirmed at Yellowstone NP, and not as much is known about them as the more extensively studied mammals and birds. The six species are the bullsnake, a subspecies of gopher snake (*Pituophis catenifer sayi*) (**Figure 1-38**), prairie rattlesnake (*Crotalis viridis*), rubber boa (*Charina bottae*), common gartersnake (*Thamnophis sirtalis*), terrestrial gartersnake (*T. elegans*), and sagebrush lizard (*Sceloporus graciosus*). Reptiles typically gather to breed or to overwinter, and their populations can be harmed by habitat disturbance or the loss of key sites. None of Yellowstone's reptiles is federally listed as threatened or endangered. All reptiles are predators that hunt and eat insects and other arthropods, fish, amphibians, other reptiles, and rodents. Reptiles in turn are eaten by larger mammalian carnivores and raptors, thus playing a central role in the GYE food chain.[80]

Figure 1-38. Bullsnake: the largest reptile in the GYE
Source: Jane Olson, National Park Service

[79] National Park Service. 2019. Yellowstone National Park: Raven. Accessed March 2, 2024 at: https://www.nps.gov/yell/learn/nature/raven.htm.
[80] National Park Service. 2021. Yellowstone National Park: Reptiles. Accessed March 2, 2024 at: https://www.nps.gov/yell/learn/nature/reptiles.htm.

Amphibians

Five species of amphibians are documented in Yellowstone NP: western tiger salamander (*Ambystoma mavortium*) (**Figure 1-39**), boreal chorus frog (*Pseudacris maculate*) (**Figure 1-40**), western toad (*Anaxyrus boreas*), Columbia spotted frog (*Rana luteiventris*), and plains spadefoot toad (*Spea bombifrons*). In addition to their other ecological roles, amphibians serve as important environmental indicators for humanity; they are exquisitely sensitive to environmental changes and thus provide scientists with valuable information and insights into ecosystem function and perturbations.[81]

Figure 1-39. Western Tiger Salamander
Source: Neal Herbert, National Park Service

According to the National Park Service:

> Amphibians are an important part of Yellowstone's aquatic and terrestrial ecosystems. Many…reptiles, birds, mammals, and fish prey on larval and adult amphibians, and amphibians, in turn, eat a variety of vertebrate and invertebrate species. Amphibians are also sensitive to disease, pollution, drought, variations in annual snowpack, and the arrival of nonnative species…[making] them valuable indicators of environmental change….Amphibian populations that are affected by one or more of these stresses may exhibit changes in their distribution or abundance. These changes can, in turn, have cascading effects on other aspects of the ecosystem.

[81] Environmental Protection Agency. 2015. EnviroAtlas Fact Sheet: Mean Amphibian Species Richness: Southwest. Available at: https://enviroatlas.epa.gov/enviroatlas/DataFactSheets/pdf/ESN/MeanAmphibianSpeciesRichness.pdf. Defenders of Wildlife. 2024. Amphibians. Accessed March 3, 2024 at: https://defenders.org/wildlife/amphibians#:~:text=Amphibians%2C%20like%20frogs%2C%20toads%20and,animals%20are%20affected%20by%20them.

> Declines in amphibian populations are occurring globally in areas where habitat destruction is pervasive, but also in protected areas. About one third of all amphibian species are believed to be threatened with extinction. Yellowstone includes some of the most climatologically and topographically complex landscapes in the lower 48 states and therefore provides a valuable study area to examine how climate may influence amphibian distribution and trends. Information about the status and trends of amphibians here may shed light on declines documented in other high-elevation locations or other protected areas around the West.[82]

Worldwide, the lethal chytrid fungus (*Batrachochytrium dentrobatidis*) alone has caused the extinction of as many as 90 species of frogs and toads in recent decades, and researchers across the planet are scrambling to save these beleaguered creatures via a variety of methods, from relocation to safer habitats to vaccination.[83] In the GYE, chytrid infections usually appear in western toads and Columbia spotted frogs after metamorphosis and are not necessarily fatal. Chytrid DNA has been identified in skin swabs from both species, though population-scale effects, if any, are still uncertain.[84]

Figure 1-40. Boreal Chorus Frog at High Lake in Yellowstone NP, July 2011
Source: Jay Fleming, National Park Service

[82] National Park Service. 2023. Yellowstone National Park: Amphibians. Accessed March 3, 2024 at: https://www.nps.gov/yell/learn/nature/amphibians.htm.
[83] Anna Gibbs. 2023. *Yale Environment 360*. As Fatal Fungus Takes Its Toll, Can We Save Frog Species on the Brink? Accessed March 3, 2024 at: https://e360.yale.edu/features/frogs-chytrid-fungus-cures#:~:text=The%20deadly%20chytrid%20fungus%20has,with%20a%20sort%20of%20vaccine.
[84] Op cit. Note #81.

Fish

Twelve native species of fish are found in Yellowstone NP,[85] the most revered of which are trout. Of these, the cutthroat trout (*Oncorhynchus clarkia*) – in the same genus (*Oncorhynchus*) as Pacific salmon and steelhead trout – is the only native trout in the park, and the subspecies of cutthroat called the Yellowstone cutthroat trout (*O. c. bouvieri*) is the most widespread native trout within the park.

Historically however, the most widely distributed and abundant subspecies of cutthroat in the region overall was the westslope cutthroat trout (*O. c. lewisi*) (**Figure 1-41**). It now occurs in less than five percent of its former range in the upper Missouri River basin. Both the Yellowstone and westslope subspecies evolved from a common ancestor; they also share food and habitat requirements. By the 1930s, westslope cutthroat were nearly extirpated from park watercourses because these had been stocked years earlier with competing trout species popular as sportfish to whet the appetites of anglers – primarily nonnative brook and brown trout (*Salvelinus fontinalis* and *Salmo trutta*, respectively, the former from the streams of eastern North America and the latter from Europe). Westslope cutthroat trout had also interbred with Yellowstone cutthroat trout and nonnative rainbow trout, diluting their unique genetic identity. In recent decades, efforts by the NPS, USFWS and other conservation stakeholders have restored the westslope cutthroat trout to dozens of stream miles and extended its range to include several lakes that were historically devoid of any fish.[86]

Figure 1-41. Westslope Cutthroat Trout
Source: Todd Koel, National Park Service

[85] National Park Service. 2024. Yellowstone National Park: Fish Ecology. Accessed March 4, 2024 at: https://www.nps.gov/yell/learn/nature/fish-ecology.htm.
[86] National Park Service. 2023. Yellowstone National Park: Westslope cutthroat trout. Available at: https://www.nps.gov/yell/learn/nature/westslope-cutthroat-trout.htm.

Among other fish species indigenous to the GYE are Arctic grayling (*Thymallus arcticus*) and mountain whitefish (*Prosopium williamsoni*); these and other native fishes are important to the ecology of the GYE. However, their abundance and distribution have been curtailed because of introduced nonnative fish, including the brook and brown trout mentioned above, as well as lake and rainbow trout (*Salvelinus namaycush* and *Oncorhynchus mykiss*, respectively). These invasive species contribute to the demise of native fish populations by competing for food and habitat, directly preying on native fish, and compromising the genetic integrity of native fish genomes through hybridization.[87]

The following statement by Todd Koel, leader of Yellowstone NP's Native Fish Conservation Program, nicely summarizes the situation with regard to GYE fisheries and native aquatic ecosystems:

> Our aquatic ecosystems are important because they are among the most pristine that remain in North America, for sure, in the contiguous 48 United States. These aquatic ecosystems support functionally intact ecosystem processes which extend both from what's in the water to what's in the terrestrial environment.[88]

Yet as observed, these ecosystems are not entirely pristine, and have been heavily and adversely affected by the deliberate introductions of nonnative fishes many years ago (as far back as the late 1800s). The invasion of Yellowstone Lake by aggressive, nonnative lake trout, replacing native cutthroats there, has negatively impacted grizzly and black bears, ospreys, and bald eagles, because lake trout spawn in the lake itself. Unlike native cutthroats, they do not do not ascend tributary streams to spawn in the spring, thus denying an important food source to the animals cited. NPS has been actively removing hundreds of thousands of lake trout annually from Yellowstone Lake to help the native cutthroat population rebound. Recreational anglers in the lake are also mandated to kill or keep any lake trout they catch in order to suppress the population.[89]

1.3 ECOSYSTEM FEATURES, FUNCTIONS, AND PROCESSES

As noted in Section 1.1, Yellowstone NP was established a century and a half ago in 1872. The aim at the time was mostly to preserve its unique and inspiring geothermal features, which include, for instance, about half the world's active geysers. At its inception, when so much of the American West was much wilder than it is today, the natural, wilderness condition of the new national park was not unexceptional. Yet as human population and associated land development and exploitation exploded in the West in the 20th and 21st

[87] National Park Service. 2024. Yellowstone National Park: Catch a Fish. Accessed March 4, 2024 at: https://www.nps.gov/yell/planyourvisit/fishing.htm.
[88] Aquatic Ecosystems of Yellowstone, a film by Ashley Siana. Available at: https://www.nps.gov/yell/learn/nature/fish-ecology.htm.
[89] Ibid.

centuries, the 2.2 million acres (3,438 square miles) of natural habitats that comprise Yellowstone NP became an ever more important refuge for the largest concentration of beleaguered wildlife – a veritable menagerie of large and rare mammals – in the Lower 48 States.[90] The recognition that Yellowstone and Grand Teton national parks were at the heart of a larger, mostly intact Greater Yellowstone Ecosystem (**Figure 1-42**) came still later.

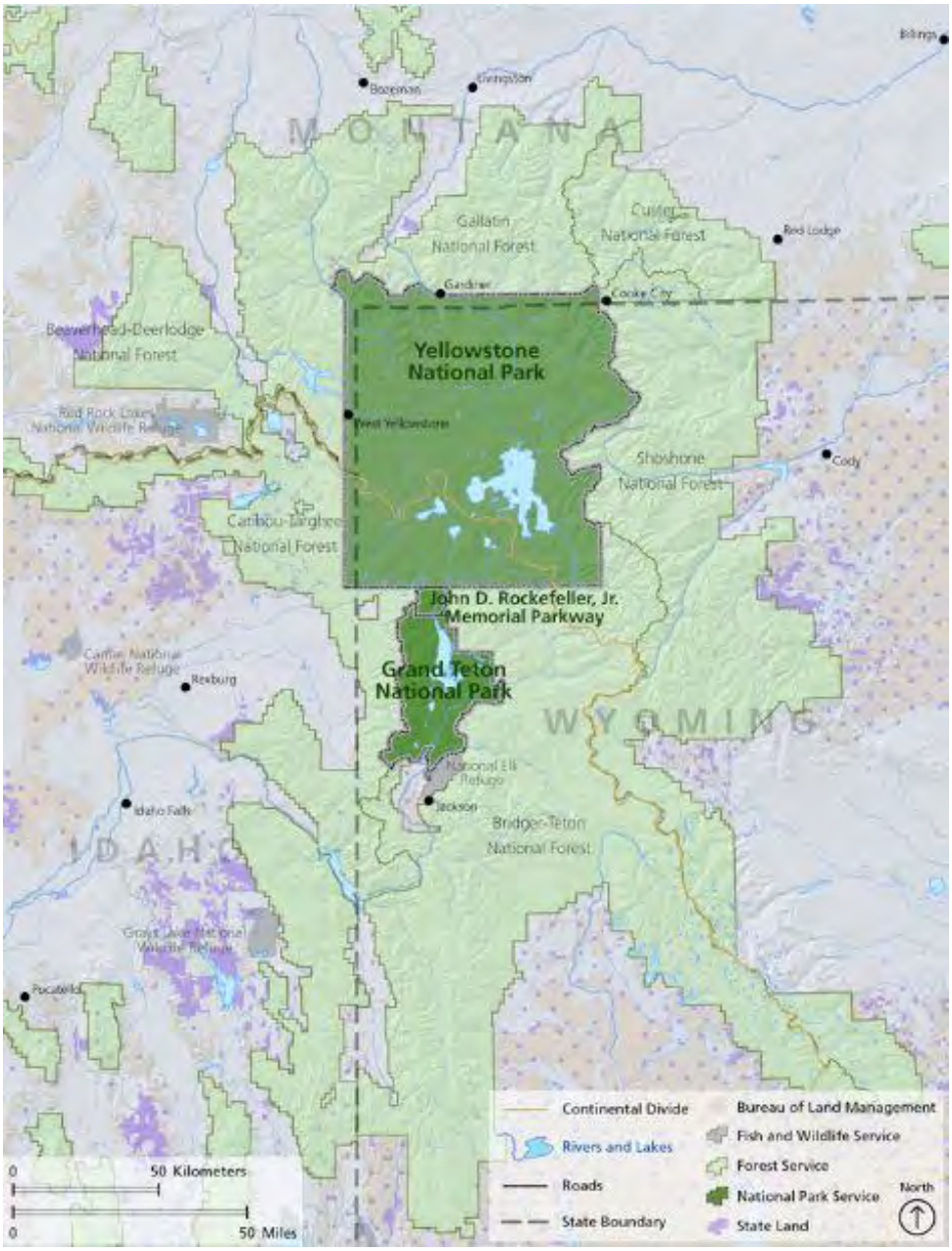

Figure 1-42. Greater Yellowstone Ecosystem
Source: National Park Service

[90] National Park Service. 2020. Yellowstone National Park: Greater Yellowstone Ecosystem. Available at: https://www.nps.gov/yell/learn/nature/greater-yellowstone-ecosystem.htm.

An ecosystem is characterized by processes and cyclical flows of energy and matter (raw materials). Precipitation, evapotranspiration, and water flow and circulation (all part of the vast hydrologic cycle), solar radiation, photosynthesis, primary consumption, predation (**Figure 1-43**), decomposition, nutrient recycling, and soil formation and erosion are all examples of ecosystem processes and cycles, which take place across a variety of spatial and temporal scales.

Figure 1-43. Predation and scavenging: grizzly bears and ravens feed at an ungulate kill
Source: Jacob W. Frank, National Park Service

As the National Park Service puts it:

> Life forms are active at all levels. Microbes beneath Yellowstone Lake thrive in hydrothermal vents where they obtain energy from sulfur instead of the sun. Plants draw energy from the sun and cycle nutrients such as carbon, sulfur, and nitrogen through the system. Herbivores, from ephydrid flies to elk, feed on the plants and, in turn, provide food for predators like coyotes and hawks. Decomposers—bacteria, fungi, other microorganisms—connect all that dies with all that is alive.
>
> The ecosystem is constantly changing and evolving. A wildland fire is one example of an integral, dynamic process. Fires rejuvenate forests on a grand scale. Some species of plants survive the intense burning to re-sprout. Some

> cones of lodgepole pines pop open only in heat generated by fires, spreading millions of seeds on the forest floor. After fire sweeps through an area, mammals, birds, and insects quickly take advantage of the newly created habitats. Fires recycle and release nutrients and create dead trees or snags that serve a number of ecological functions, such as the addition of organic matter to the soil when the trees decompose.[91]

Ecosystem cycles and processes are quite evident in the GYE's "northern range" (**Figure 1-44**) – the broad grasslands along the Yellowstone and Lamar rivers in the northern part of Yellowstone NP and beyond the park boundary into southwestern Montana. The northern range supports one of the densest and most diverse concentrations of large, free-ranging mammals anywhere on the planet. Large numbers of ungulates (e.g., bison, elk, moose) overwinter and forage here, where elevations are lower and snow not as deep. The relatively high ecosystem integrity of the northern range has furnished wildlife biologists and ecosystem researchers with a "natural laboratory" that has increased our scientific understanding of predator-prey dynamics and other ecological processes.[92]

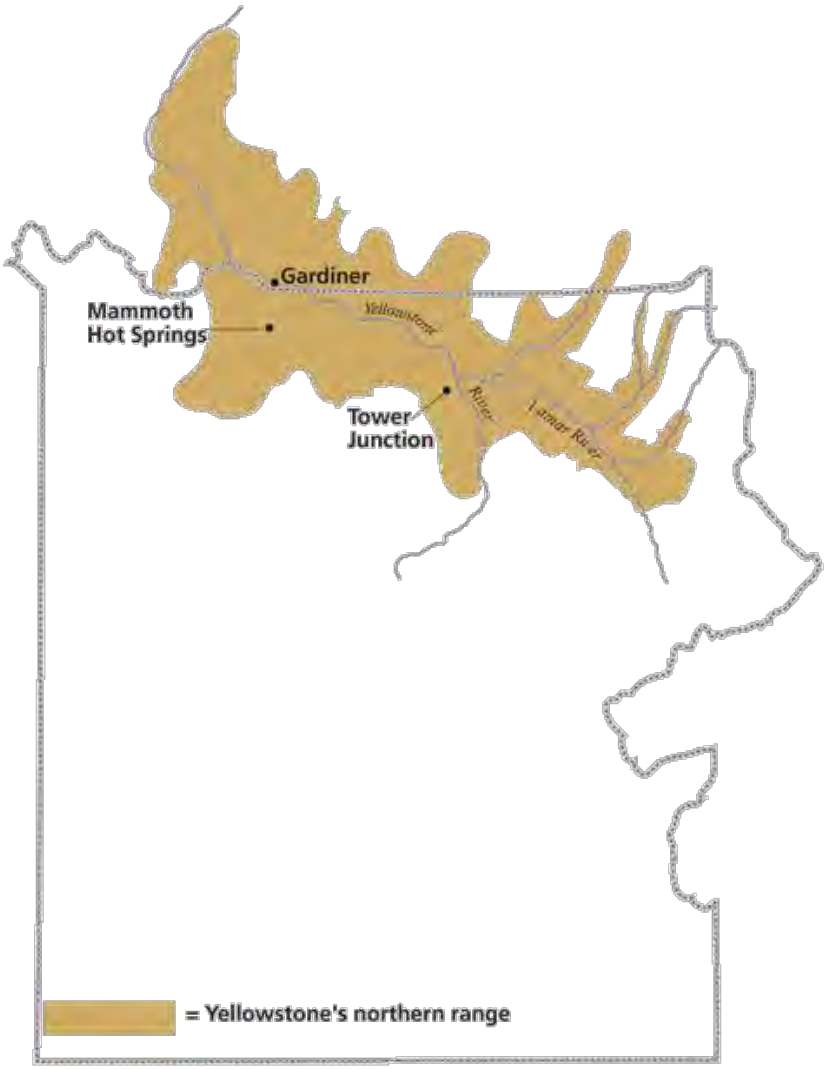

Figure 1-44. Northern Range of Yellowstone

[91] National Park Service. 2022. Yellowstone National Park: Cycles and Processes. Accessed March 9, 2024 at: https://www.nps.gov/yell/learn/nature/cycles-and-processes.htm.
[92] Ibid.

Outside of Alaska, the GYE is the only substantial ecosystem in the United States whose wildlands have retained or restored their full historical array of vertebrate wildlife species. In addition to its relative wildness and low human population density, the GYE's wildlife abundance and diversity is due, in good measure, to its diverse habitats, from alpine areas above timberline to lower-elevation grasslands and sagebrush; there are hydrothermal areas (**Figure 1-45**), forests, meadows, riparian zones, and aquatic habitats. Each habitat at a given elevation and landform is connected by continuous terrain, by the hydrologic corridors of watercourses, and by circulating air.[93]

Figure 1-45. Morning Glory Pool, Yellowstone National Park

In the three decades since the restoration of wolves to the GYE, biologists have discovered dimensions of ecological complexity and intricacy extending well beyond readily observable large mammals alone. For example, they have learned that elk and bison carcasses are ecosystems unto themselves: at least 57 species of just beetles are associated with ungulate carcasses on Yellowstone's northern range. But only one of these 57 feeds on the meat of ungulates; the others prey on other small insect scavengers, mostly fly and beetle larvae. Still

[93] Ibid.

others eat microscopic fungal spores.[94] Though unseen or unappreciated by the casual human eye, the shrinking ungulate carcass is a source of vital nutrients to thousands of creatures large and small.

Migration is usually associated with migratory birds such as waterfowl or neotropical migrants, which fly south every autumn from their northern breeding grounds in North America to overwinter in less harsh climes and habitats where food is still available. However, in the GYE, a number of ungulates also migrate (on the ground, not in the air!) in search of literally greener pastures. Grasses and other herbs and forbs (non-woody plants) are a key part of the diets of GYE herbivores such as bighorn sheep, bison, elk, mule deer, pronghorn, and moose. These foragers migrate seasonally across the landscape in pursuit of their plant food sources when they are most nutritious. Typically, GYE ungulates consume green plants in the spring in lower-elevation winter ranges and then in the summer ascend to higher-elevation meadows and grasslands. In the late autumn, they descend back down to their lower-elevation winter ranges and eat mostly dead, lower-quality foodstuffs, when higher-elevation summering areas are subject to frigid temperatures, harsh winds, and deeper snows.[95] **Figure 1-46** depicts migratory routes of various ungulates in the GYE. The key point is that many of these routes cross jurisdictional boundaries, dangerous highways, from public lands to private lands, or from one land management status to another.

Wildland fire is a key natural "disturbance" and ecosystem process that regularly shapes the GYE; indeed, the GYE is a fire-adapted ecosystem (**Figure 1-47**), like many in the West. Various native plants possess evolutionary adaptations to not only survive but even thrive after periodic fires. Fire affects nutrient cycling and the composition and structure of plant communities on the landscape.[96] Fire regimes and "return intervals" (the average time interval between repeat fire events on any given site) in the western states changed radically with the arrival of Euro-American settlers who typically tried to suppress most naturally-occurring fires in the 1800s and well into the 1900s. Think of Smokey the Bear's original messaging ("Only YOU can prevent forest fires!") implying that all wildland fires were bad. Over time, this approach inevitably fostered the accumulation of "fuel," that is, flammable plant material (organic matter) such as trees (alive and dead), grasses, shrubs, fallen leaves and pine needles.[97] Suppression of all fires tended to result in less frequent but far more damaging conflagrations. Nowadays, in contrast to earlier misinformed policies based on a misunderstanding of fire ecology, government land management agencies generally aim to restore fire's role as a natural process on their lands when and where this is practicable.

[94] Ibid.
[95] Ibid.
[96] National Park Service. 2023. Yellowstone National Park: Fire. Accessed March 10, 2024 at: https://www.nps.gov/yell/learn/nature/fire.htm.
[97] U.S. Department of the Interior. No date. Fuels Management. Available at: https://www.doi.gov/wildlandfire/fuels#:~:text=What%20are%20fuels%3F,chances%20of%20extreme%20wildfire%20events.

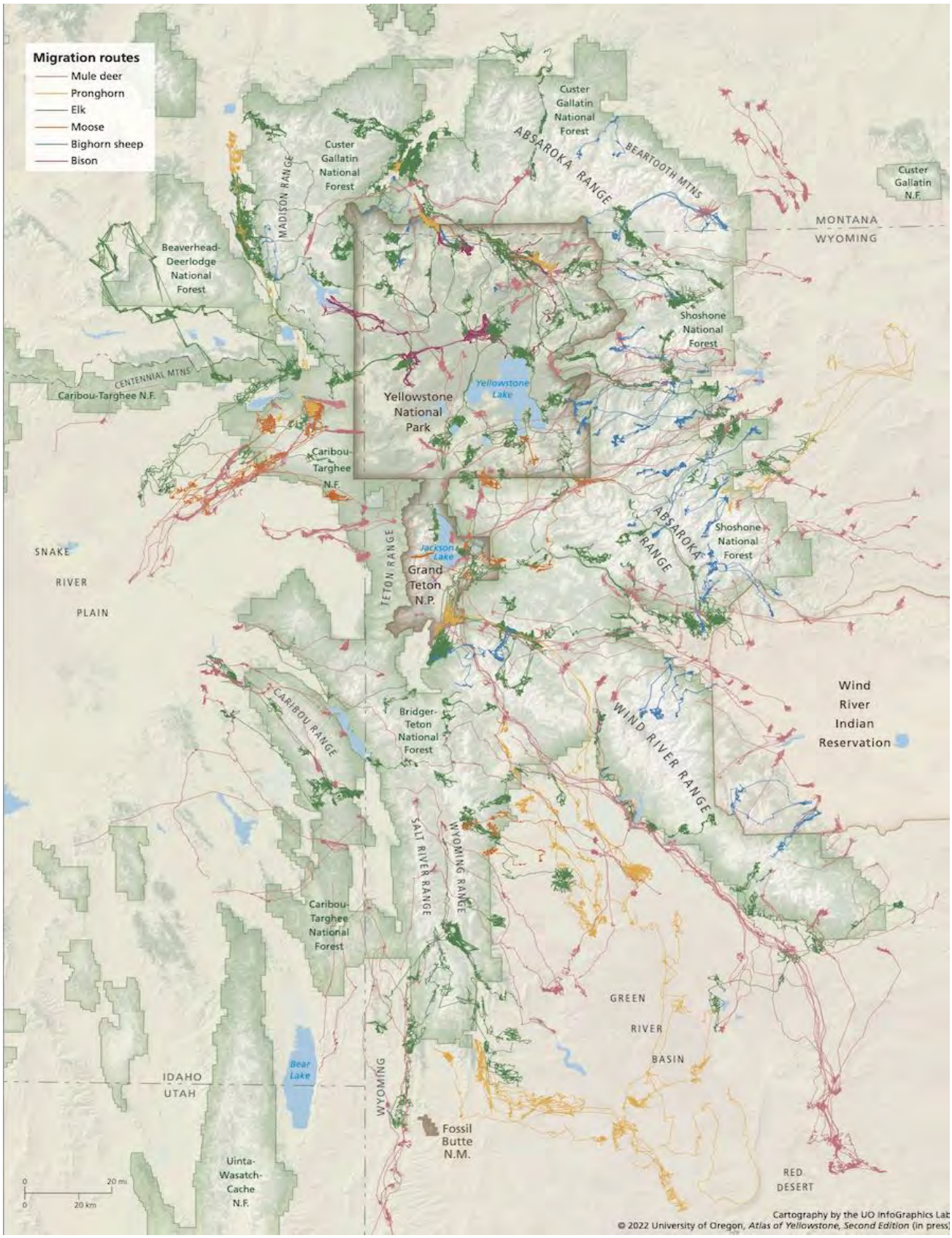

Figure 1-46. GYE Migration Routes of Ungulates

Figure 1-47. The GYE is a fire-adapted ecosystem
Source: National Park Service

1.4 YELLOWSTONE AND GRAND TETON NATIONAL PARKS: AWE-INSPIRING LANDSCAPES

As noted earlier, both Yellowstone and Grand Teton National Parks were first set aside mostly for their geologic wonders and scenic landscapes (**Figure 1-48**) rather than their biological resources and ecosystem values and functions per se. Yellowstone NP alone boasts more than 10,000 hydrothermal features (**Figures 1-49 and 1-50**) and half of the world's active geysers.[98]

Figure 1-48. Mount Moran (12,610') and Jackson Lake in Grant Teton National Park

[98] National Park Service. 2023. 150 years of Yellowstone. Available at: https://www.nps.gov/yell/getinvolved/150-years-of-yellowstone.htm.

Figure 1-49. Grand Prismatic Spring
Photo credit: Mike Goad at Pixabay

Figure 1-50. Yellowstone Hydrothermal Feature in Winter

The Grand Tetons (**Figure 1-51**) have been described as "perhaps the most distinctive of the granite giants which comprise the Rocky Mountains. A series of sharp pyramids of naked rock, the peaks stand like sharks' teeth against the sky."[99] Their peaks jut more than 7,000 vertical feet above the valley bottom known as Jackson Hole (**Figure 1-52**). The park's elevation ranges from 6,320 feet above sea level on the valley floor (still more than a mile high), dominated by sagebrush, past the coniferous forest zones and timberline to 13,770 feet on the sheer, craggy summit of the Grand Teton itself.[100]

The rugged Yellowstone Canyon (**Figure 1-53**) below the dramatic waterfall on the upper Yellowstone River is world renowned. The national park's meadows and mostly coniferous forests (**Figure 1-54**) and rolling landscapes possess not just habitat value for wildlife but also immense scenic value for urban-weary human beings as an extensive, protected open space area in a world that seems ever more crowded, congested, and cluttered.

Figure 1-51. Garnet Canyon in Grand Teton NP
Source: National Park Service

[99] Yellowstone Association / Grand Teton Natural History Association. 1962. Colter's Hell and Jackson's Hole. Available online at: https://www.nps.gov/parkhistory/online_books/grte1/contents.htm
[100]

Figure 1-52. Teton Range jutting skyward above the mostly flat valley floor
Source: Adams/NPS

Figure 1-53. Yellowstone Canyon

Figure 1-54. Expansive, uplifting GYE natural landscapes soothe the soul

1.5 National Forests, National Wildlife Refuges, and Other Federal Lands in the GYE

1.5.1 National Forests

The two national parks in the GYE comprise just a fraction of its land area. Other federal lands managed by the U.S. Forest Service (USFS) (national forests or NFs), U.S. Fish and Wildlife Service (USFWS) (national wildlife refuges or NWRs), and Bureau of Land Management (BLM) comprise the bulk of the lands under federal management in the GYE. The USFS is in the U.S. Department of Agriculture (USDA), while the USFWS and the BLM are both in the U.S. Department of Interior, as is the National Park Service (NPS). National forests and BLM lands are both managed for multiple uses, including watershed protection, wildlife (both game and non-game), fisheries, wilderness, biodiversity, timber harvest, mining and other resource extraction (e.g., oil and gas drilling), and both consumptive (e.g., hunting and fishing) and non-consumptive (e.g., hiking, backpacking, camping, wildlife observation, photography) outdoor recreation.

The five national forests in the GYE are the Custer Gallatin National Forest (NF) and the Beaverhead-Deerlodge NF in Montana, north and west of Yellowstone NP, respectively; the Shoshone NF (America's first National Forest) and the Bridger-Teton NF in Wyoming, east

of Yellowstone and Grand Teton NPs; and the Caribou-Targhee NF in Idaho, west and southwest of Yellowstone and Grand Teton NPs. These national forests are spectacular "jewels of the West." The Custer Gallatin NF, for example, includes the majestic Beartooth Mountains (**Figure 1-55**), which embrace the highest 41 mountain peaks in Montana, including Granite Peak, the highest point in the state at 12,799 ft.[101]

Figure 1-55. Beartooth Mountains in the Custer Gallatin National Forest
Source: U.S. Forest Service

Over 300 lakes and 10 major sub-alpine tundra plateaus are found on the Beartooth Ranger District. More than 700 glaciers are as well, though they are shrinking along with most other glaciers in the American and Canadian Rockies due to climate change. However truncated they appear now, in the recent geologic past (during the Pleistocene or Ice Age), these glaciers helped gouge and sculpt the Beartooths into the striking shapes they possess today. The Beartooth Highway is one of the most scenic mountain drives in the entire country. It climbs to 10,947ft and offers breathtaking views and access to many superlative recreation opportunities.[102]

Several decades ago, the USFS promoted timber harvest (logging), oil and gas exploration, livestock grazing, and other environmentally damaging resource extraction and exploitation activities on GYE national forests, even in areas close to Yellowstone and Grand Teton national parks. The Targhee NF, for example, had conducted extensive clearcutting of old-

[101] U.S. Forest Service. No date. Custer Gallatin National Forest: Beartooth Mountains. Available online at: https://www.fs.usda.gov/detail/custergallatin/?cid=STELPRD3830236.
[102] Ibid.

growth forests on Yellowstone NP's western boundary and "left the area a wasteland for bears and elk." The Bridger-Teton NF was proceeding with oil and gas leases near the two parks. A "massive" gold mine was proposed for the Gallatin NF just upstream from Yellowstone. Moreover, none of the GYE national forests were proposing any major new formal wilderness designations, even though several large roadless areas remained relatively unspoiled.[103] (There are now 10 congressionally-designated national wilderness areas on national forest lands within the GYE.)

Environmental groups fought most of the first-generation Land and Resource Management Plans (LRMPs or Forest Plans) in the GYE national forests, arguing that they did not appropriately balance nature conservation vis-à-vis resource extraction and commodity production within the context of the Forest Service's pursuit of multiple use. According to Professor Keiter, "the appeals did not immediately the overall commitment to commodity production." But, he adds, "much has changed since then, however, and the Forest Service is a different agency today with different priorities and challenges." Resource extraction has been significantly curbed on the GYE national forests, as "an array of new issues concerning wildlife habitat, migration corridors, recreation, wildfire, and climate change have come to the fore."[104]

Figure 1-56. Green Lakes region of the Bridger Wilderness in the Bridger-Teton NF
Photo credit: G. Thomas, Public Domain

[103] Keiter. Op cit. Footnote #2.
[104] Keiter. Op cit. Footnote #2.

1.5.2 National Wildlife Refuges

According to USFWS, on national wildlife refuges, "wildlife comes first," that is, native wildlife abundance and diversity takes precedence over other management considerations, such as recreation or natural resource extraction. NWRs typically do allow for public use, including wildlife observation and photography, environmental education and interpretation, and sport hunting and fishing, provided that these uses are compatible with the wildlife purposes for which a given refuge was established. Depending on circumstances, they can even permit a limited amount of resource extraction, such as forest thinning or selective tree harvest, provided that they serves habitat management and are determined to be "compatible" with the refuge purposes.

Three national wildlife refuges are located in the GYE: Red Rock Lakes NWR in Montana (**Figure 1-57**), Grays Lake NWR in Idaho, and the National Elk Refuge in Wyoming. By way of example, Red Rock Lakes NWR, according to USFWS, "offers a unique experience being the largest wetland complex in the Greater Yellowstone Ecosystem and where different wildlife habitats converge. The Refuge offers landscape beauty and wildlife viewing opportunities that few places can match."[105]

Figure 1-57. Centennial Mountains reflected in Culver Pond at Red Rock Lakes NWR
Photo credit: USFWS Volunteer James "Newt" Perdue

Red Rock Lakes Refuge has a remote wilderness setting; to preserve its wilderness character and sense of solitude, facilities are minimal and travel and recreation off the established

[105] U.S. Fish and Wildlife Service. No date. Red Rock Lakes National Wildlife Refuge. Accessed March 31, 2024 at: https://www.fws.gov/refuge/red-rock-lakes.

roads is on foot only. The 53,000+ acre refuge serves as a corridor for large mammals like the grizzly bear moving between the GYE and other parts of Idaho and Montana. 32,350 acres are designated wilderness. Elk, deer and pronghorn call reside on the refuge from spring through fall, as do migratory waterfowl and songbirds (**Figure 1-58**).[106]

Figure 1-58. Yellow warbler in willow thicket at Red Rock Lakes NWR
Photo credit: USFWS Volunteer James "Newt" Perdue

Public facilities include a visitor center, two primitive campgrounds, and two easy hiking trails. The refuge's conservation efforts aim to furnish habitat for breeding and staging migratory birds, native fishes, and both transitory and resident wildlife. Migratory or year-round resident vertebrates include grizzly bears, black bears, elk, deer (mule and whitetail), Shiras moose, pronghorn, trumpeter swans, tundra swans, bald eagles, golden eagles, sandhill cranes, ground squirrels, badgers, wolves, coyotes, foxes, martens, all species of Pacific Flyway waterfowl in the Pacific Flyway, and many species of neotropical migrant songbirds. Hunting and fishing are allowed on the refuge, in addition to wildlife and landscape observation and photograph.[107]

Recent and ongoing research projects at Red Rock Lakes NWR include:

- Integrated restoration strategy for cheatgrass in sagebrush landscapes
- Impacts of cheatgrass on sagebrush songbirds and their habitat

[106] Ibid.
[107] Ibid.

- Nesting ecology of trumpeter swans
- Breeding ecology of sage-grouse in southwestern Montana
- Restoration of sagebrush meadow habitat
- Linking beaver dam affected flow dynamics to upstream passage of Arctic grayling winter survival, resource use, and hypoxia impacts to Arctic grayling in Upper Red Rock Lake
- Mountain camera trap surveys for carnivore inventory
- Mountain bluebird nest box trail
- Invasive plant removal for enhanced wildlife habitat
- Aspen reforestation
- Duck banding
- Effects of grazing on grassland and shrubland vegetation and bird communities
- Grassland restoration[108]

Grays Lake NWR (**Figure 1-59**), 30 miles north of Soda Springs, Idaho, was established in 1965 to conserve some of historic Grays Lake, a high-elevation 22,000-acre bulrush marsh that boasts the largest breeding population of migratory sandhill cranes (**Figure 1-60**) on the continent.[109]

Figure 1-59. Grays Lake NWR
Source: Ken Scheffler, USFWS

[108] U.S. Fish and Wildlife Service. No date. Red Rock Lakes National Wildlife Refuge: Projects and Research. Accessed April 2, 2024 at: https://www.fws.gov/refuge/red-rock-lakes/what-we-do/projects-research.
[109] U.S. Fish and Wildlife Service. No date. Grays Lake National Wildlife Refuge. Accessed April 9, 2024 at: https://www.fws.gov/refuge/grays-lake.

Figure 1-60. Sandhill Cranes in Flight
Source: Bruce Ellingson, USFWS

The 24,700-acre National Elk Refuge (**Figure 1-61**) north of Jackson, Wyoming, provides winter habitat and a feeding station for more than 7,500 elk migrating south from Grand Teton and Yellowstone national parks. This NWR, with its high wintertime elk population densities, has long attracted many winter visitors who enjoy observing elk, but is also problematic because high elk densities facilitate the spread of diseases to which they are susceptible. The refuge was established in 1912, as noted earlier, because increasing development in the area blocked their traditional seasonal migratory routes. This had led to conflicts with ranchers, as hungry elk converged on hay supplies intended for livestock. Public indignation at the sight of starving elk persuaded Congress to establish the National Elk Refuge. The USFWS has seasonally fed overwintering elk ever since, a controversial practice that has triggered lawsuits and challenges from various conservation and animal welfare groups.[110]

Figure 1-61. National Elk Refuge
Photo credit: Ams100272, Wikipedia Creative Commons

[110] Keiter. Op cit. Footnote #2.

1.5.3 Bureau of Land Management Lands

The Department of the Interior's Bureau of Land Management (BLM) administers large tracts of federal land on the fringes of the GYE that are available for a variety of land uses ("multiple use"), including winter range for ungulates and other wildlife species, consumptive and non-consumptive and motorized and non-motorized outdoor recreation, and non-renewable resource extraction activities such as hard rock mining and oil and gas drilling. Lower-elevation BLM lands serve valuable ecological functions, such as furnishing crucial habitat for the declining sage-grouse (**Figure 1-62**) (listed as a "sensitive species") and other wildlife, as well as migratory and dispersal corridors that connect isolated wildlife populations, thus helping preserve genetic diversity and population viability.[111]

Figure 1-62. Greater Sage-Grouse – Male sage-grouse (background) and female sage-grouse (foreground) during the spring for the breeding season where males compete for female attention
Source: Jeannie Stafford, USFWS

1.5.4 Other Federal Land Designations

Ten distinct congressionally-declared national wilderness areas, specifically preserved under the Wilderness Act of 1964, have been designated within the GYE's national forests since 1966. Formally declared wilderness areas are provided with a higher or more stringent degree of habitat protection than USFS management would otherwise ensure – logging and mining are not permitted, for instance. The John D. Rockefeller Jr. Memorial Parkway, named for conservationist and philanthropist John D. Rockefeller Jr., is a scenic road that connects Yellowstone and Grand Teton NPs and protects 24,000 acres. The Snake River, famous for its fly fishing for trout, flows by the parkway on its way south to Jackson Lake.

[111] Keiter. Op cit. Footnote #2.

1.6 TRIBAL LANDS

Established in the late 19th century, the 2.2-million acre Wind River Indian Reservation (**Figure 1-63**) is the 7th-largest Native American reservation in the United States. Located in the southeastern corner of the GYE, it is home to the Eastern Shoshone (**Figure 1-64**) and Northern Arapaho tribes.[112]

Figure 1-63. Wind River Range on the Indian Reservation of that name in Wyoming
Source: Jennifer Strickland, USFWS

Figure 1-64. Eastern Shoshone flag

[112] Wind River Indian Reservation. Available online at: https://windriver.org/destinations/wind-river-indian-reservation/.

Back in the 1930s, the Reservation established a 180,000-acre roadless area in the Wind River Range, just a decade after America's first ever designated wilderness area (the Gila in New Mexico, 1924), and several decades before the enactment of the National Wilderness Act of 1964. Shoshone and Arapaho have re-established a number of wildlife and large game populations, including moose, wolf, elk, mule and whitetail deer, bighorn sheep, and pronghorn, while managing hunts that promote both recreation and conservation. In 2016, the Shoshone reintroduced ten bison to the Reservation – the first seen there since 1885 – starting what is planned to eventually be a herd numbering one thousand.[113] The Northern Arapaho reestablished a small herd by relocating 10 bison to the Reservation in 2019.[114]

With the purchase of a tribal fishing license, the Wind River Reservation permits access to non-tribal anglers on the southern half of the reservation, including the tribal roadless area in the majestic Wind River Range. Hikers and mountaineers can climb 13,810 ft Gannett Peak, the highest point in Wyoming, which is on the Reservation. The Reservation also licenses contractors and outfitters for whitewater rafting and sport fishing in Wind River Canyon.

There are legacy contamination issues on the Reservation from abandoned uranium mining, milling, and tailings that some studies suggest have led to an elevated incidence of cancer, kidney disease, and other serious ailments for residents.[115]

1.7 CONSERVATION NON-PROFITS AND LAND TRUSTS

The Trust for Public Land (TPL), the Nature Conservancy (TNC), and other NGO conservation partners have helped protect the ecological integrity of the GYE by purchasing and protecting more than 200,000 acres of important wildlife habitat threatened by developers at such places as Taylor Fork, Duck Creek, and Sun Ranch.[116]

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[113] Jack McNeel. 2016. Wind River Reservation Receives First Bison Since 1885. *Indian Country Today*. December 31. https://indiancountrymedianetwork.com/news/environment/wind-river-reservation-receives-first-bison-since-1885/.

[114] Savannah Maher. 2019. Northern Arapaho Tribe Welcomes First Buffalo Herd. Wyoming Public Radio. October 16. Accessed April 14, 2024 at: https://www.wyomingpublicmedia.org/tribal-news/2019-10-16/northern-arapaho-tribe-welcomes-first-buffalo-herd#stream/0.

[115] Ron Feemster. 2013. Study ties cancer on the Wind River Indian Reservation to uranium tailings site. *WyoFile*. June 25. Accessed April 14, 2024 at: https://wyofile.com/study-relates-cancer-on-the-wind-river-indian-reservation-to-uranium-tailings-site/. Tristan Ahtone. 2012. Cancer-Riddled Wind River Reservation Fights EPA Over Uranium Contamination. *Indian Country Today*. Accessed April 14, 2024 at: https://indiancountrymedianetwork.com/news/cancer-riddled-wind-river-reservation-fights-epa-over-uranium-contamination/. Johnnye Lewis et al. 2017. Mining and Environmental Health Disparities in Native American Communities. *Current Environmental Health Reports*. 4(2): 130–141. Available online at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5429369/.

[116] TPL. 2024. Greater Yellowstone Ecosystem. Accessed April 14, 2024 at: https://www.tpl.org/our-work/greater-yellowstone-ecosystem. TNC. Priority Landscapes: Greater Yellowstone. Accessed 9-24 at: https://www.nature.org/en-us/about-us/where-we-work/priority-landscapes/yellowstone/.

1.8 PRIVATE LANDS – RURAL AND DEVELOPED

This study utilizes land use, cover, and ownership data from the National Resources Inventory (NRI) of the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). Table 1 in the most recent NRI (data up through 2017, published in September 2020) has several major land tenure or ownership classifications or categories, the most fundamental of which is federal versus non-federal lands.[117] It is the non-federal land – almost all of it privately owned except for municipal parks and the like – on which development, urbanization, and urban / suburban sprawl are taking place.

Table 1-1 shows the area of federal versus non-federal lands in the 20 Idaho, Montana, and Wyoming counties in the Greater Yellowstone Ecosystem. It also shows the total area, by county and in aggregate, of non-federal rural land and developed land in 2017, the most recent year for which data are available from the NRI. In looking at acreages and percentages in this table, one thing to bear in mind is that while the GYE includes 20 counties according to the definition used in this study, not all of each county is necessarily located within the GYE proper. This is what accounts for the lower percentage of federal land comprising each county and in aggregate than shown in other treatments of land tenure / ownership in the GYE.

Table 1-1. 2017 Surface Acreage of Federal and Non-Federal Lands in the 20 GYE Counties of ID, MT, and WY*

County	Total Non-Federal Rural Land	Developed Land	Federal Land	Total Surface Area of County	% Federal Land
Idaho					
Bear Lake	322.7	9.3	296.5	670.3	44.2%
Bonneville	577.0	42.3	579.9	1,219.2	47.6%
Caribou	633.9	27.7	452.6	1,136.2	39.8%
Clark	392.3	4.9	738.9	1,136.8	65.0%
Fremont	470.7	16.0	710.2	1,215.1	58.4%
Madison	220.9	14.1	61.7	299.3	20.6%
Teton	176.9	10.6	96.0	284.6	33.7%
Totals ID GYE Counties	**2,794.4**	**124.9**	**2,935.8**	**5,961.5**	**49.2%**

[117] U.S. Department of Agriculture. 2020. *Summary Report: 2017 National Resources Inventory*, Natural Resources Conservation Service, Washington, DC, and Center for Survey Statistics and Methodology, Iowa State University, Ames, Iowa.
https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/results/

County	Total Non-Federal Rural Land	Developed Land	Federal Land	Total Surface Area of County	% Federal Land
Montana					
Beaverhead	1,453.3	24.0	2,088.1	3,586.0	58.2%
Carbon	695.1	10.7	574.0	1,289.9	44.5%
Gallatin	908.4	45.2	701.3	1,672.5	41.9%
Madison	1,100.6	16.1	1,057.9	2,186.0	48.4%
Park	945.7	14.0	974.6	1,942.6	50.2%
Stillwater	926.7	15.9	205.5	1,155.8	17.8%
Sweet Grass	891.4	14.8	289.4	1,200.6	24.1%
Totals MT GYE Counties	**6,921.2**	**140.7**	**5,890.8**	**13,033.4**	**45.2%**
Wyoming					
Fremont	2,582.2	123.0	3,262.4	6,016.0	54.2%
Hot Springs	577.0	7.0	541.8	1,127.1	48.1%
Lincoln	671.9	21.6	1,924.8	2,631.1	73.2%
Park	1,138.7	38.2	3,454.3	4,646.5	74.3%
Sublette	789.0	19.7	2,412.8	3,249.4	74.3%
Teton	140.8	22.3	2,520.2	2,818.0	89.4%
Totals WY GYE Counties	**5,899.6**	**231.8**	**14,116.3**	**20,488.1**	**68.9%**
All GYE Counties	**15,615.2**	**497.4**	**22,942.9**	**39,483.0**	**58.1%**

*In thousands of acres

Source: Table 1 in U.S. Department of Agriculture. 2020. *Summary Report: 2017 National Resources Inventory* (Footnote #116).

Note that the total area of the 20 GYE counties in Table 1 is approximately 39.5 million acres, about twice the size of the estimated 20 million acres often cited as one estimate of the area of the GYE. Within this expanded GYE corresponding to the entire area of all 20 counties combined, federal lands comprise 58 percent of aggregate area. Even with all the population growth and development in recent decades within these 20 counties, the total area of developed land in 2017, according to the NRI, is just short of 500,000 acres (497,400 acres), compared to the much larger areas of non-federal rural land (15,615,200 acres) and federal land (22,942,900 acres). In sum, in 2017, developed land comprised just 1.3 percent of the GYE counties, which is what allows for the continuing existing of wilderness, wildlife,

farming, and ranching on a robust scale. However, even this seemingly miniscule degree of development is already having an unquestionably adverse effect on the ecological values, functions, and raw natural beauty that drew many residents to the GYE and environs in the first place.

For example, the population of Bozeman, MT (**Figure 1-65**), the largest city in the GYE, has nearly tripled in size since 1980. Even more problematic is the fragmentation of wildlife habitat and the blockage or interference with ungulate migration corridors from exurban and low-density sprawl, development, and associated vehicular traffic (**Figure 1-66**).

Figure 1-65. Aerial View of Bozeman, MT in 2008
Credit: Feetyouwear, CC BY 2.0 <https://creativecommons.org/licenses/by/2.0>, via Wikimedia Commons

Figure 1-66. Increasing vehicular traffic in parts of the GYE can pose a death-trap for some wildlife

1.9 A PLETHORA OF ENCROACHING THREATS TO THE GYE

1.9.1 Loving the Greater Yellowstone Ecosystem to Death

In his classic 1967 history of shifting American attitudes toward wilderness, *Wilderness and the America Mind*,[118] University of California, Santa Barbara professor Roderick Nash warned in the closing pages that Americans were in danger of loving their national parks and wilderness areas to death. Encroachment and infringement upon erstwhile pristine beauty, wild haunts and habitats, and soaring solitude loomed large. As nature and wilderness in the United States receded under pavement, asphalt, and sprawling subdivisions during the 20th century, and especially in the post-World War II era, when the national population and economy began booming with a vengeance, visitation to our parks was booming as well, triggering traffic jams in Yosemite Valley, crowds at Old Faithful, and long lines at the entrance to Glacier National Park along Going-to-the-Sun Highway. Smog from Los Angeles and the Page, Arizona coal-fired power plant blighted views across the no-longer-pristine and timeless Grand Canyon from the South Rim.

In the 20th century, the American population nearly quadrupled and the American West grew even faster. Visitation to Yellowstone and Grand Teton national parks grew faster still. **Figures 1-67 to 1-70** and **Tables 1-2 and 1-3** depict this dramatic surge in numbers.

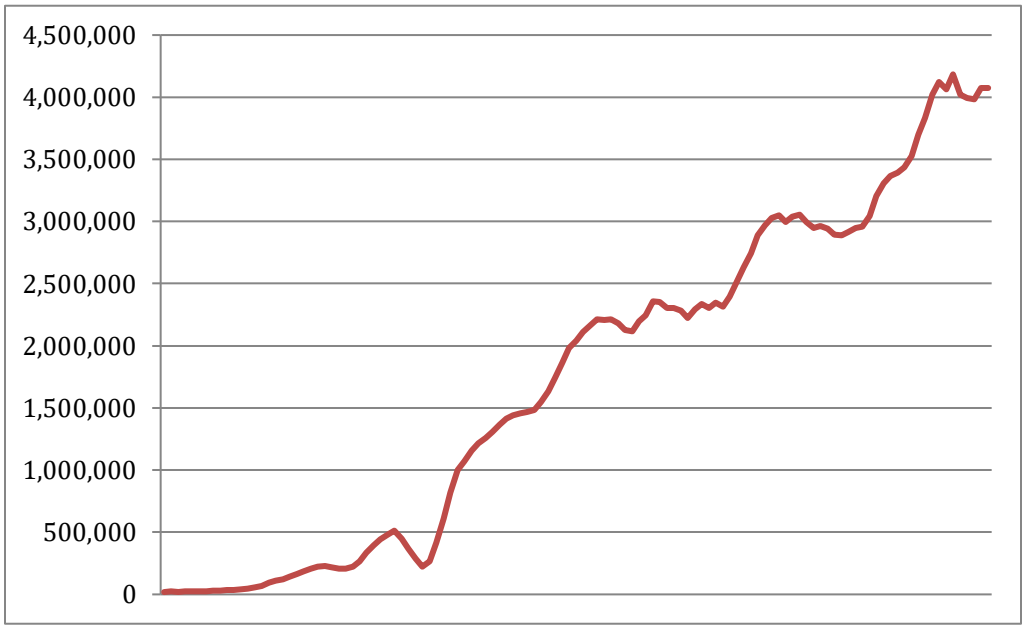

Figure 1-67. Yellowstone National Park Annual Recreation Visitation, 1904-2023*
*In 5-year running averages to dampen year-to-year fluctuations

[118] Roderick Frazier Nash. 1967. *Wilderness and the American Mind*. Yale University Press. Several subsequent editions have been published as well.

Table 1-2. Annual Recreation Visits to Yellowstone National Park, 1904-2023

1904	13,727	1934	260,775	1964	1,929,300	1994	3,046,145
1905	26,188	1935	317,998	1965	2,062,500	1995	3,125,285
1906	17,182	1936	432,570	1966	2,130,300	1996	3,012,171
1907	16,414	1937	499,242	1967	2,210,000	1997	2,889,513
1908	19,542	1938	466,185	1968	2,229,700	1998	3,120,830
1909	32,545	1939	486,936	1969	2,193,700	1999	3,131,381
1910	19,575	1940	526,437	1970	2,297,300	2000	2,838,233
1911	23,054	1941	579,696	1971	2,120,500	2001	2,758,526
1912	22,970	1942	185,746	1972	2,236,888	2002	2,973,677
1913	24,929	1943	61,696	1973	2,061,700	2003	3,019,375
1914	20,250	1944	86,593	1974	1,928,900	2004	2,868,317
1915	51,895	1945	189,264	1975	2,239,500	2005	2,835,651
1916	35,849	1946	807,917	1976	2,519,200	2006	2,870,295
1917	35,400	1947	937,776	1977	2,481,900	2007	3,151,343
1918	21,275	1948	1,018,279	1978	2,618,380	2008	3,066,580
1919	62,261	1949	1,131,159	1979	1,892,908	2009	3,295,187
1920	79,777	1950	1,110,524	1980	2,000,269	2010	3,640,185
1921	81,651	1951	1,163,894	1981	2,521,831	2011	3,394,326
1922	98,223	1952	1,350,295	1982	2,368,897	2012	3,447,729
1923	138,352	1953	1,326,858	1983	2,347,242	2013	3,188,030
1924	144,158	1954	1,328,900	1984	2,222,027	2014	3,513,484
1925	154,282	1955	1,368,500	1985	2,226,159	2015	4,097,710
1926	187,807	1956	1,457,800	1986	2,363,756	2016	4,257,177
1927	200,825	1957	1,595,900	1987	2,573,194	2017	4,116,524
1928	230,984	1958	1,442,400	1988	2,182,113	2018	4,115,000
1929	260,697	1959	1,408,700	1989	2,644,442	2019	4,020,288
1930	227,901	1960	1,443,300	1990	2,823,572	2020	3,806,306
1931	221,248	1961	1,524,100	1991	2,920,537	2021	4,860,242
1932	157,624	1962	1,925,200	1992	3,144,405	2022	3,290,242
1933	161,938	1963	1,872,500	1993	2,912,193	2023	4,501,382

The total or cumulative number of recreation visits to Yellowstone NP from 1904 to 2023 exceeded two hundred million, 203,750,110 to be exact.[119] Almost 84 million of these visits have occurred in the 21st century alone (2000-2023), 41 percent of the cumulative all-time visits in just 20 percent of the time since record-keeping began. Again, reflects the fact that visitation pressures on the national park's resources, facilities, and infrastructure are growing.

[119] National Park Service. Values in table and both graphs all from same source. Available online at: https://irma.nps.gov/Stats/Reports/Park/YELL

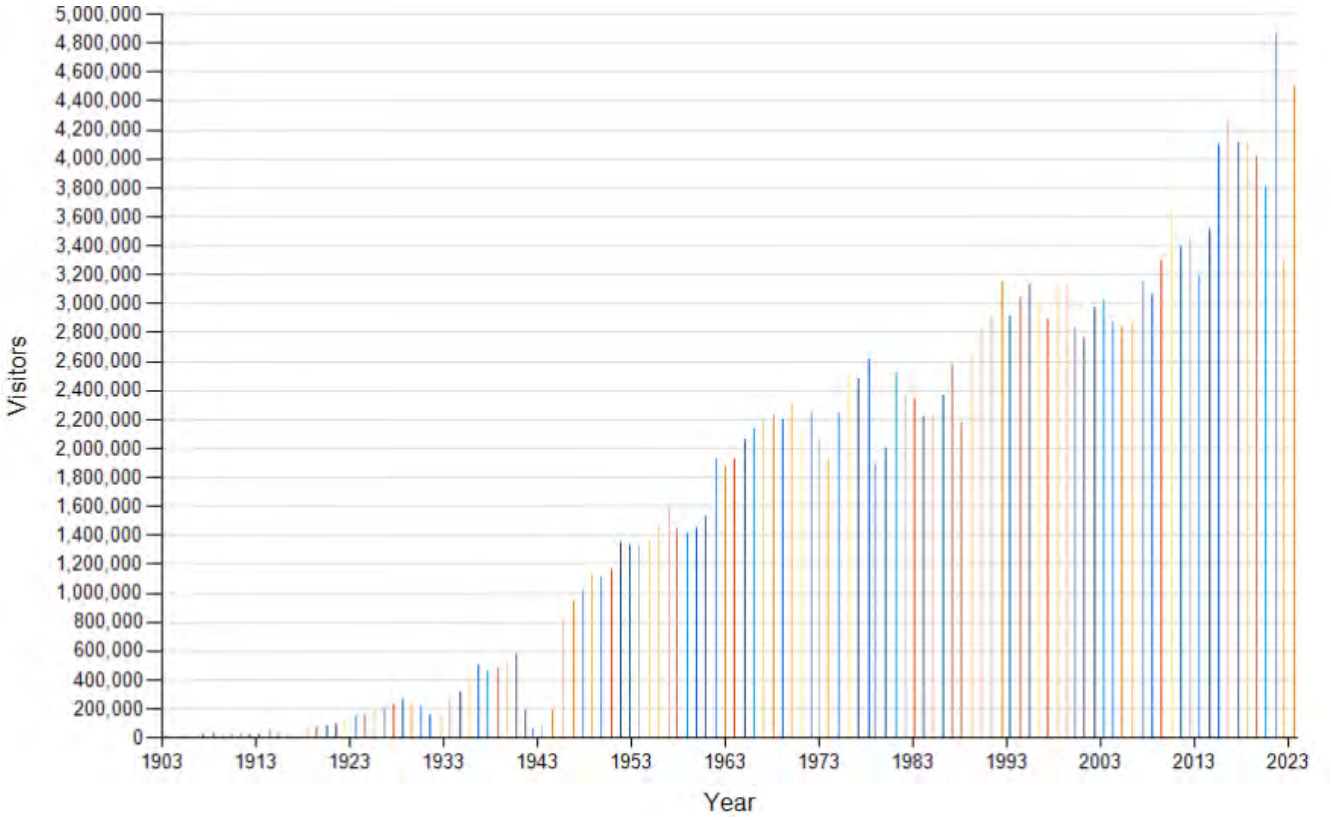

Figure 1-68. Total Recreation Visits to Yellowstone National Park, 1904-2023

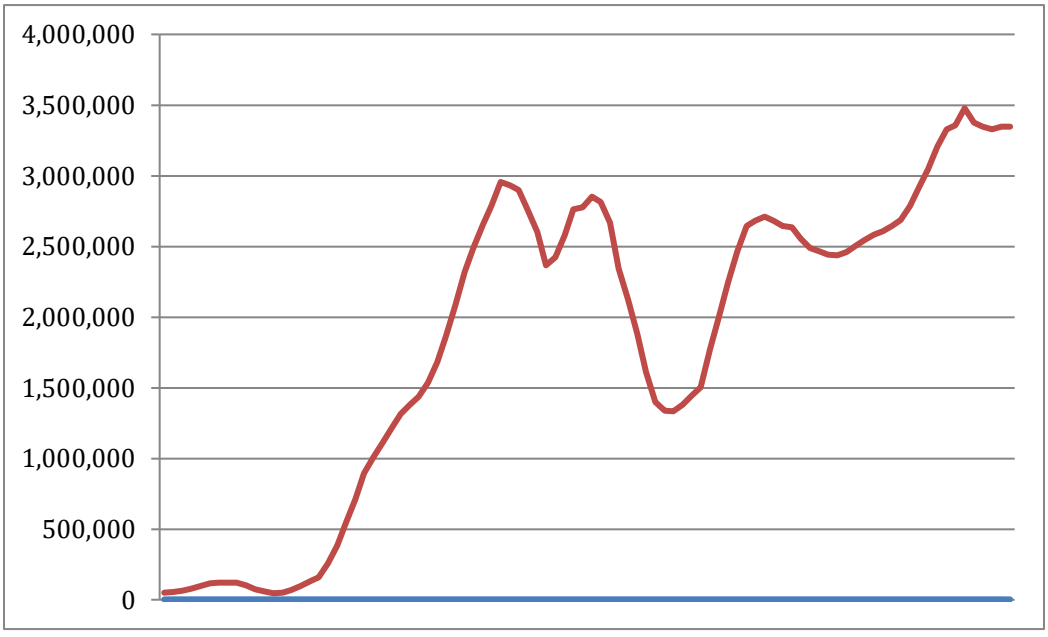

Figure 1-69. Grand Teton National Park Annual Recreation Visitation, 1929-2023*
*In 5-year running averages to dampen year-to-year fluctuations

Table 1-3. Annual Recreation Visits to Grand Teton National Park, 1929-2023

1929	51,500	1953	942,966	1977	3,258,000	2001	2,535,108
1930	60,000	1954	1,003,500	1978	3,160,026	2002	2,612,629
1931	62,000	1955	1,104,700	1979	2,446,171	2003	2,355,693
1932	40,000	1956	1,197,200	1980	2,555,627	2004	2,360,373
1933	42,500	1957	1,306,300	1981	2,643,644	2005	2,463,442
1934	75,000	1958	1,428,500	1982	2,534,029	2006	2,406,476
1935	100,000	1959	1,529,600	1983	1,532,035	2007	2,588,574
1936	125,000	1960	1,429,900	1984	1,360,898	2008	2,485,987
1937	135,000	1961	1,492,400	1985	1,334,483	2009	2,580,081
1938	153,353	1962	1,799,400	1986	1,306,322	2010	2,669,374
1939	87,133	1963	2,158,800	1987	1,450,791	2011	2,587,437
1940	103,324	1964	2,456,800	1988	1,232,691	2012	2,705,256
1941	125,489	1965	2,507,000	1989	1,331,659	2013	2,688,794
1942	33,808	1966	2,673,100	1990	1,588,253	2014	2,791,392
1943	8,203	1967	2,643,700	1991	1,625,752	2015	3,149,921
1944	19,978	1968	2,970,300	1992	1,744,636	2016	3,270,076
1945	41,349	1969	3,134,400	1993	2,568,689	2017	3,317,000
1946	136,441	1970	3,352,500	1994	2,540,699	2018	3,491,151
1947	142,975	1971	2,556,400	1995	2,731,015	2019	3,405,614
1948	153,054	1972	2,490,266	1996	2,733,439	2020	3,289,638
1949	166,506	1973	2,228,600	1997	2,658,762	2021	3,885,230
1950	189,286	1974	2,392,900	1998	2,757,060	2022	2,806,223
1951	637,785	1975	2,173,500	1999	2,680,025	2023	3,417,106
1952	785,343	1976	2,834,700	2000	2,590,624	**Total**	**171,510,364**

Between 1929, when recreational visitation record-keeping began at Grand Teton NP, and 2023, the most recent year for which recreational visit data have been compiled, more than 170 million visitors have descended on the park – 171,510,364 to be exact.[120] Almost 68.5 million visits have occurred in the 21st century alone (2000-2023), 40 percent of the cumulative park visitation in 26 percent of the period of record. As with Yellowstone NP, this reflects Grand Teton's rising visitation numbers.

[120] National Park Service. Values in table and both graphs for Grand Teton NP all from same source. Available online at: https://irma.nps.gov/Stats/SSRSReports/Park%20Specific%20Reports/Annual%20Park%20Recreation%20Visitation%20(1904%20-%20Last%20Calendar%20Year)?Park=GRTE

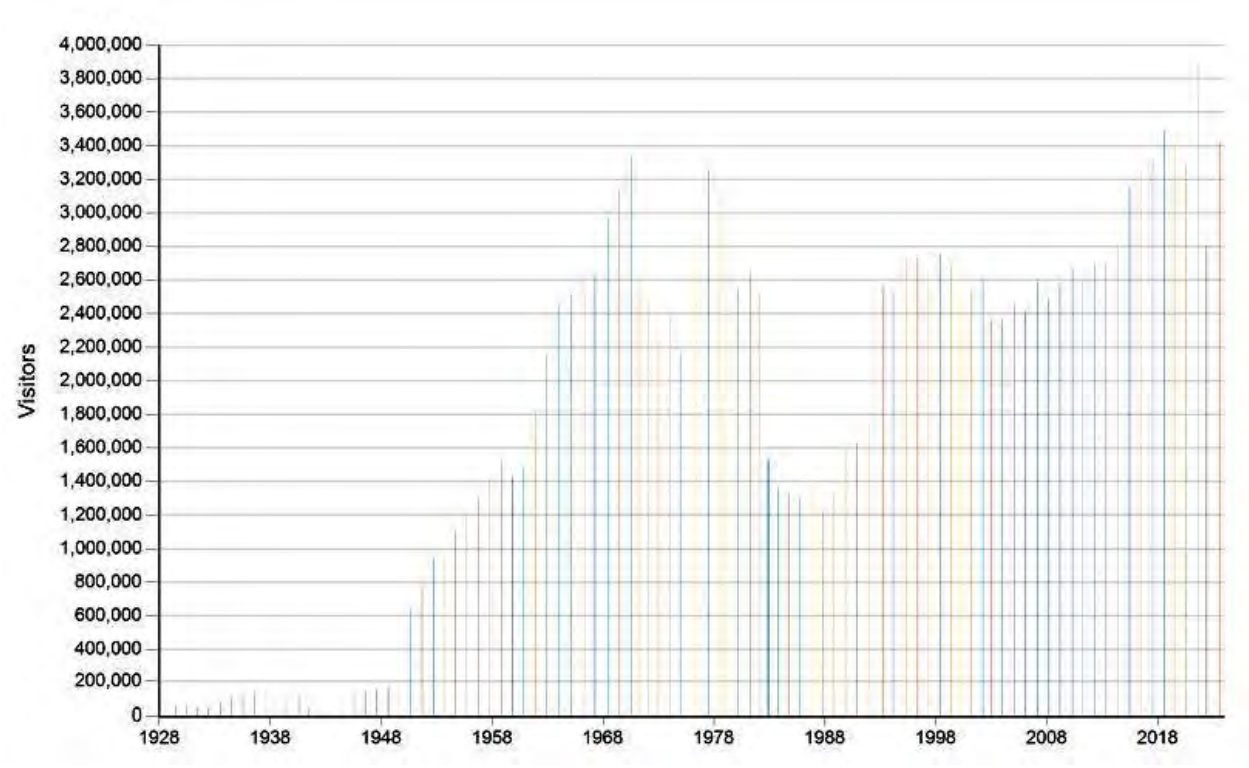

Figure 1-70. Total Recreation Visits to Grand Teton National Park, 1929-2023

NPS is well aware of the issues posed by the crush of visitors to Yellowstone and Grand Teton national parks, drawn to the magnet of their natural beauty, wildness, and wildlife. "More and more people want to experience it," writes NPS. Since 2008 alone, annual visitation to Yellowstone has surged by almost 40%. This had led to congested parking lots, traffic jams – often caused by motorists understandably excited to see the large mammals for which the parks are famous (**Figure 1-71**), soil erosion, trampling of vegetation, and unhygienic and malodorous conditions at overrun restrooms. Accompanying the crowds and traffic are a 90 percent increase in motor vehicle accidents (+90%), 60 percent rise in ambulance use, and 130 percent jump in search and rescue efforts. At the same time, staffing and funding levels have remained more or less stagnant over the past decade.[121]

NPS notes:

> The challenges posed by high levels of summer visitation and changing visitor use patterns are comprehensive, complex, and affect not only Yellowstone visitors and

[121] National Park Service. 2023. Visitor Use Management. Accessed online on 5-4-2023 at: https://www.nps.gov/yell/learn/management/visitor-use-management.htm.

employees, but gateway communities, surrounding public lands, and other national and regional stakeholders. Difficult decisions lie ahead, and we'll need your help to find compromises that balance the protection of resources with a shared desire to

experience the world's first national park.

Figure 1-71. Traffic jam in Yellowstone's Hayden Valley due to bison and heavy visitation
Source: Jacob W. Frank, National Park Service

NPS was established in 1916 within the Department of the Interior – more than four decades after Yellowstone NP itself was created – and the National Park Service Organic Act and subsequent policy mandate it to both accommodate public use and to preserve the natural resources under its jurisdiction. NPS recognizes that it must balance these competing or sometimes conflicting aims.

1.9.2 GYE Population Growth, Development, and Sprawl

Investigating these interconnected phenomena is the point of this study and they will be explored in depth in the coming chapters. Suffice it to say here that the combined population of the 20 GYE counties grew by 58 percent from 1982 to 2017, the period of study. This led to essentially permanent conversion to developed land of a substantial acreage of wildlife habitats, farmland, ranchland, and open space generally within the GYE. A more succinct way of characterizing this phenomenon is "habitat loss." Accompanying this population growth, land development, and habitat loss was habitat fragmentation, increasing residential vehicular traffic on GYE roads (with concomitant adverse ramifications for wildlife mortality – roadkill – from collisions with larger animals and running over smaller ones), and

increasing recreational pressures on public lands and competition between competing users and user groups.

1.9.3 Wildlife Diseases

"Historically, diseases were viewed as minor players in the ecosystem relative to predators, competitors, and resources," wrote disease ecologist Paul C. Cross of the U.S. Geological Survey in 2007.[122] Yet increasing human activity in and around the GYE, and the greater contact with the outside world this represents, would raise the risk of exposure to emerging and novel infectious diseases that can adversely affect formerly remote, inaccessible wildlife and fish populations.

Incurable Chronic Wasting Disease (CWD) has already been mentioned above. Caused by naturally-occurring proteins called prions that kill brain cells, it infects elk, deer, and moose (collectively known as cervids); the fatality rate in infected cervids is 100 percent. First detected in wild deer only in 1981, it is now widespread among some cervids in certain places in the East and Midwest (31 states in all, as well as several countries). In 2023, CWD was detected for the first time in a GYE mule deer carcass. Its arrival had long been anticipated by wildlife biologists. While there is still no evidence that CWD can be passed from diseased animals to humans, the Centers for Disease Control (CDC) recommends that hunters take reasonable precautions to avoid putting themselves at risk.[123]

Brucellosis has also been mentioned previously. Unlike CWD, it does not kill infected mammals such as bison, elk, and cattle, but it does cause abortions and stillbirths. While largely eliminated from domestic cattle herds, GYE bison and elk continue to be reservoirs of infection, with up to 60 percent of Yellowstone bison testing positive. Therefore the livestock industry and state agencies oppose the unrestricted migration of wild bison outside of Yellowstone NP, which effectively caps the size of the bison herd to the limited carrying capacity of the available range inside the park alone.

Populations of some or all of the 4-5 species of amphibians in the GYE (one salamander, one toad, and three frogs) have declined in at least some portions of their GYE ranges, and diseases such as those caused by ranaviruses and chytrid fungi, related at least in part to

[122] Paul C. Cross. 2007. The Invisible Hand of Disease. *Yellowstone Science: Disease Ecology and Wildlife Health in the Greater Yellowstone Ecosystem*. 15(2). Available online at: https://www.nps.gov/yell/learn/upload/YS_15_2_sm.pdf.
[123] Margaret Osborne. 2023. 'Zombie Deer Disease' Documented in Yellowstone for the First Time. *Smithsonian*. November 23. Retrieved online 5-5-2024.

increasing human presence and activities, may be one contributing factor.[124] Parvovirus, distemper, hepatitis, and mange have all been implicated in wolf illness or mortality in the GYE.[125]

Whirling disease, caused by an introduced (non-native) protozoan parasite, has caused sharp population declines among native trout in the Northern Rockies. Whirling disease turns a trout's spine crooked, making it spin in circles (hence, "whirling") and unable to feed effectively. Native to Europe, and spread by humans, whirling disease now extends about half of U.S. states.[126] It was first detected in the native Yellowstone cutthroat trout population in 1998, and this keystone species is highly susceptible to whirling disease. Native cutthroats once provided a significant source of protein in the spring and summer for grizzly bears. Whirling disease and introduction of the non-native lake trout (discussed below) in Yellowstone Lake both contributed to major cutthroat trout population declines.[127]

This is just a brief synopsis of the ecology of disease in the GYE. Overall, the threat posed to GYE mammalian and fish populations by indigenous, introduced, and emergent pathogens and the diseases they cause will likely increase as long as human populations and activities in the region also continue to do so.

1.9.4 Invasive Species

Invasive species – also called exotics or non-natives – are organisms that have been introduced either deliberately or accidentally by humans into new habitats or geographic regions (often transported across oceans to entirely new continents). Most organisms transported to new and novel ecological settings perish, but others do not. Indeed, some thrive to the extent that they become noxious or harmful pests, because here they often lack the assortment of natural bio-controls – herbivores, predators, parasites, or pathogens – with which they have coevolved across the millennia, and which keep them from proliferating unchecked in their native range.[128] Invasive species are an enormous problem of global proportions; they are one of the leading threats to biodiversity across the biosphere as well as

[124] Paul Stephen Corn. 2007. Amphibians and Disease: Implications for Conservation in the Greater Yellowstone Ecosystem. Pp. 11-16 in *Yellowstone Science.* (See note 121).
[125] Douglas W. Smith and Emily Almberg. 2007. Wolf Diseases in Yellowstone National Park. Pp. 17-19 in *Yellowstone Science: Disease Ecology and Wildlife Health in the Greater Yellowstone Ecosystem*.
[126] Mike Koshmrl. 2018. The Comeback of the Cutthroat. *Jackson Hole*. May 21. Accessed online 5-5-2024 at: https://jacksonholemagazine.com/the-comeback-of-the-cutthroat/.
[127] Todd M. Koel et al. 2007. Whirling Disease and Native Cutthroat Trout of the Yellowstone Lake Ecosystem. Pp. 25-33 in *Yellowstone Science: Disease Ecology and Wildlife Health in the Greater Yellowstone Ecosystem*.
[128] Invasive Plant Atlas of the United States. 2018. Accessed online on 5-6-2024 at: https://www.invasiveplantatlas.org/index.cfm.

imposing huge economic costs mounting to hundreds of billions of dollars annually.[129] Worldwide, more than a third of all introductions of invasives have taken place just since 1970.[130]

Invasive species have also taken hold and taken a toll in the GYE. For example, botanists have surveyed an estimated 225 non-native species of plants in Yellowstone NP alone, compared to approximately 1,386 native plant species in the park. According to NPS:

> Invasive, non-native plants can displace native plant species, including some endemic to the park's geothermal habitats, change the nature of vegetation communities and affect fire frequency and the distribution, foraging activity, and abundance of wildlife. These changes can profoundly affect the entire ecosystem. For example, nonnatives that are unpalatable to wildlife may replace preferred native plants, leading to changes in grazing activity. In turn, this stresses plants not adapted to grazing.
>
> Invasive plants have altered views of the park's cultural landscapes and historic districts. Seeds may be spread by people and their vehicles, wild and domestic animals, and sand and gravel used for construction and maintenance work. The most vulnerable areas have been disturbed by human use….Restoring native plants in an area that has become infested is extremely difficult.[131]

NPS emphasizes that it is unrealistic to control all invasive plants. Thus, park staff set priorities based on the threat a given exotic infestation poses to native plant communities and wildlife, as well as the prospects for its successful control. While some smaller or contained infestations can be nipped in the bud (i.e., eradicated) if caught and treated early, other invasive species, such as spotted knapweed (*Centaurea maculosa*), have become so widespread that preventing them from spreading still further has become the primary aim.[132] As a general rule, the greater the level of human activity in or adjacent to a habitat, the greater the probability of problems stemming from invasive plants.

Invasive species affect aquatic as well as terrestrial habitats in the GYE. The "poster child" for this is the lake trout (*Salvelinus namaycush*), a char (related to salmon and trout) native to parts of North America (primarily Canada and Alaska) but not to Yellowstone NP. Because of their popularity with anglers, for many years lake trout were introduced by humans to non-native waters in North America, Europe, Asia, and Africa. Back in the 1890s, they were

[129] Helen Regan. 2023. Invasive species cost the world $423 billion every year and are causing environmental chaos, UN report finds. Cable News Network (CNN). 5 Sept. Retrieved 5-5-2024 at: https://www.cnn.com/2023/09/05/world/invasive-species-global-threat-report-climate-scn-intl-hnk/index.html#.
[130] International Union for the Conservation of Nature (IUCN). 2017. Invasive alien species on the rise worldwide. Retrieved online 5-5-2024 at: https://www.iucn.org/news/secretariat/201702/invasive-alien-species-rise-worldwide.
[131] National Park Service, Yellowstone National Park. 2020. Invasive Plants. Available online at: https://www.nps.gov/yell/learn/nature/invasive-plants.htm.
[132] Ibid.

stocked legally into the park's Shoshone, Lewis, and Heart lakes, and then, nearly a century later, in the 1980s they were introduced accidentally or illegally into Yellowstone Lake itself.[133]

NPS fisheries biologists describe what happened next as a veritable "take-over" of this waterbody. Lake trout are ravenous predators, and they "were reproducing and proliferating at a rapid rate." Scientists verified that the larger ones fed heavily on native Yellowstone cutthroat trout, effectively annihilating the population of the lake's native trout species. A panel of fisheries experts suggested that gillnetting (**Figure 1-72)** would be the best way to remove lake trout and thus protect and restore the native Yellowstone cutthroat trout population. (Gillnets, used primarily in commercial fishing of Pacific salmonids, are a type of aquatic netting with mesh sized such that the narrower heads of targeted fish fit through but their wider bodies are snagged.) However, this would require a long-term, possibly permanent commitment on the part of NPS. To date, millions of lake trout have been removed from the lake. As mentioned earlier, this has had positive ramifications throughout the terrestrial food web, because lake trout do not spawn in shallow tributary streams of Yellowstone Lake and recovering cutthroat trout do, so that they are available as a food source to raptors and bears.[134]

Figure 1-72: Gillnetting Lake Trout in Yellowstone Lake
Source: National Park Service

[133] Andrew R. Munro et al. 2006. Where Did They Come From? Natural Chemical Markers and Date of Lake Trout Introduction in Yellowstone Lake. *Yellowstone Science* 14(2):4 -12. Spring 2006. Available online at: https://www.nps.gov/yell/learn/upload/YS_14_2_sm.pdf.
[134] National Park Service, Yellowstone National Park. 2024. Fish Management. Retrieved online 5-9-2024 at: https://www.nps.gov/yell/learn/management/fish.html .

In conclusions, the greater the proliferation and presence of human beings and the hustle and bustle of our assorted activities in the vicinity of the GYE, the greater the threat posed by invasive species to ecosystem integrity, and the greater the ecological and economic cost – and ultimately, the infeasibility – of controlling or managing them becomes. As the National Wildlife Federation sums it up: "Invasive species are spread primarily by human activities."[135]

1.9.5 Climate Change

As a result of accelerating human activities around the globe associated with human population growth and economic growth – primarily increasing combustion of fossil fuels (coal, oil, natural gas) to generate energy and the clearing of forests – the concentration of carbon dioxide (CO_2) (**Figure 1-73**) and other greenhouse gases (GHGs) in our atmosphere has been increasing implacably for the better part of the past century or more.

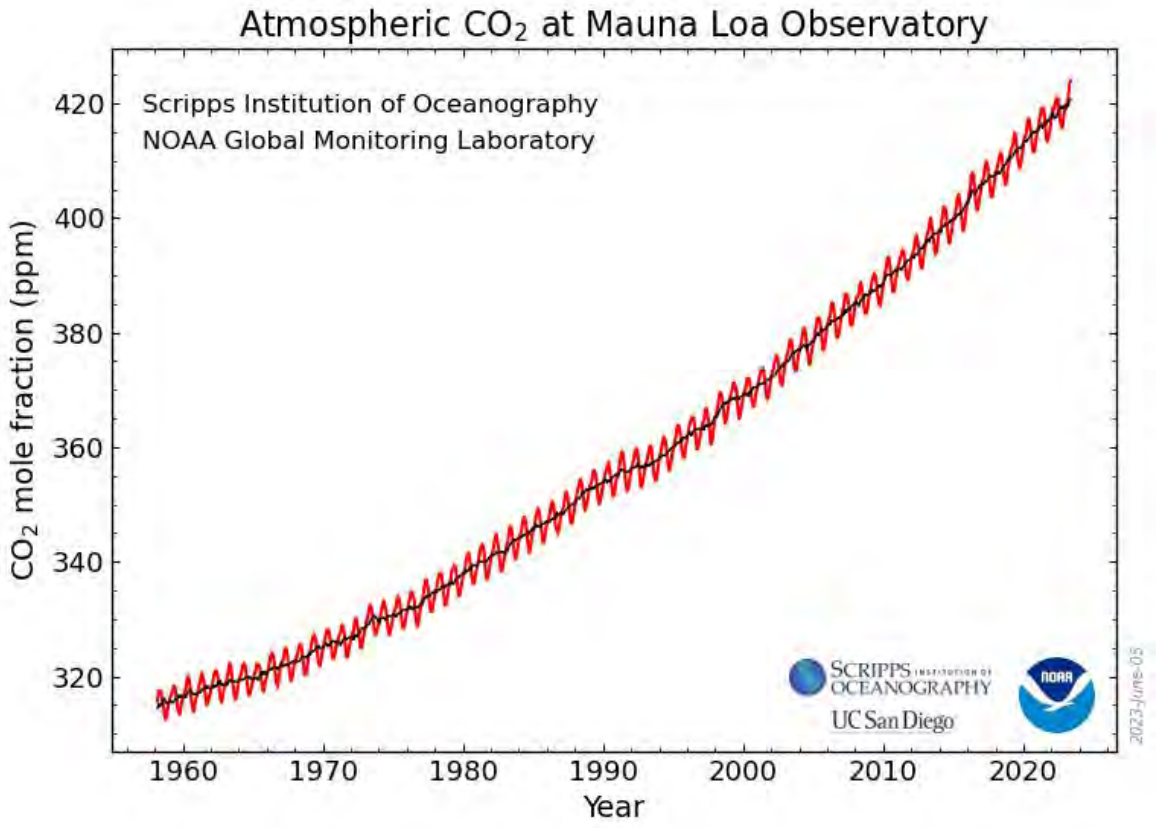

Figure 1-73. Long-term, steady rise in atmospheric CO_2 concentration recorded at the Mauna Loa Observatory in Hawaii, 1958-2023

Source: National Oceanic and Atmospheric Administration (NOAA)[136]

[135] National Wildlife Federation. No date. How Invasive Species Spread. Accessed online 5-9-2024 at: https://www.nwf.org/Educational-Resources/Wildlife-Guide/Threats-to-Wildlife/Invasive-Species.

[136] National Oceanic and Atmospheric Administration (NOAA). 2023. Broken record: atmospheric carbon dioxide levels jump again: Annual increase in Keeling Curve peak is one of the largest on record.

Natural causes of climate variability include both astronomical factors, such as the Earth's Milankovitch (orbital) cycles and changes in solar activity,[137] and terrestrial factors such as persistent large volcanic eruptions or changes in ocean currents.[138]

However, since the 1800s, increased burning of fossil fuels to provide the energy demanded by a rapid increase in the human population and its economic activities (e.g., production and consumption) has been the major driver of observed climate change.[139] Burning these fossil fuels emits CO_2 into the atmosphere. CO_2 is the leading GHG, which act like a blanket enveloping the Earth, trapping the sun's heat and raising temperatures in both the lower atmosphere (troposphere) and the upper layers of the ocean.[140]

As a result of rising anthropogenic GHG emissions over the past two centuries, and an associated increase in GHG concentrations in the atmosphere, the average temperature at the Earth's surface has risen to about 1.1 degrees Celsius above what it was before the industrial revolution. The planetary surface is now the warmest it has been in the last 100,000 years, and the last decade (2011-2020) is the warmest on record (**Figure 1-74**).[141]

Anthropogenic heating of the climate is already having discernable effects in the GYE and is likely to result in even greater effects in the future. Mountain glaciers are shriveling and disappearing due to warmer air temperatures. Snowpack is shrinking, altering the timing, temperature, and quantity of flows in watercourses. Ecologists anticipate these changes in baseline hydrology alone will affect the composition and distribution of both flora and fauna. The wildfire season has lengthened, and wildland fires have become larger, more frequent, and intense. The 2016 fire season burned more acreage than any year in the past century, except for the catastrophic fires of 1988. Invasion of exotic/invasive species and outbreaks of pests, pathogens, and disease are expected to occur more often.[142]

Accessed 5-11-2024 at: https://www.noaa.gov/news-release/broken-record-atmospheric-carbon-dioxide-levels-jump-again.

[137] NASA Science Editorial Team. 2020, updated March 18, 2024. Milankovitch (Orbital) Cycles and Their Role in Earth's Climate. Accessed online 5-11-2024 at: https://science.nasa.gov/science-research/earth-science/milankovitch-orbital-cycles-and-their-role-in-earths-climate/.

[138] United Nations. No Date. What is Climate Change? Accessed online 5-11-2024 at: https://www.un.org/en/climatechange/what-is-climate-change.

[139] Intergovernmental Panel on Climate Change. 2021. Climate change widespread, rapid, and intensifying. Accessed 5-11-2024 at: https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/.

[140] Op. cit. Note 137.

[141] National Aeronautics and Space Administration (NASA), National Earth Observatory. 2022. Global Temperatures. Accessed 5-11-2024 at: https://earthobservatory.nasa.gov/world-of-change/global-temperatures. World Meteorological Organization. 2021. 2020 was one of the three warmest years on record. 15 January. Accessed 7-13- 2023 at: https://wmo.int/media/news/2020-was-one-of-three-warmest-years-record#.

[142] National Park Service, Yellowstone National Park. 2020. Climate Change. September 25. Retrieved online on 5-11-2024 at: https://www.nps.gov/yell/learn/nature/climate-change.htm.

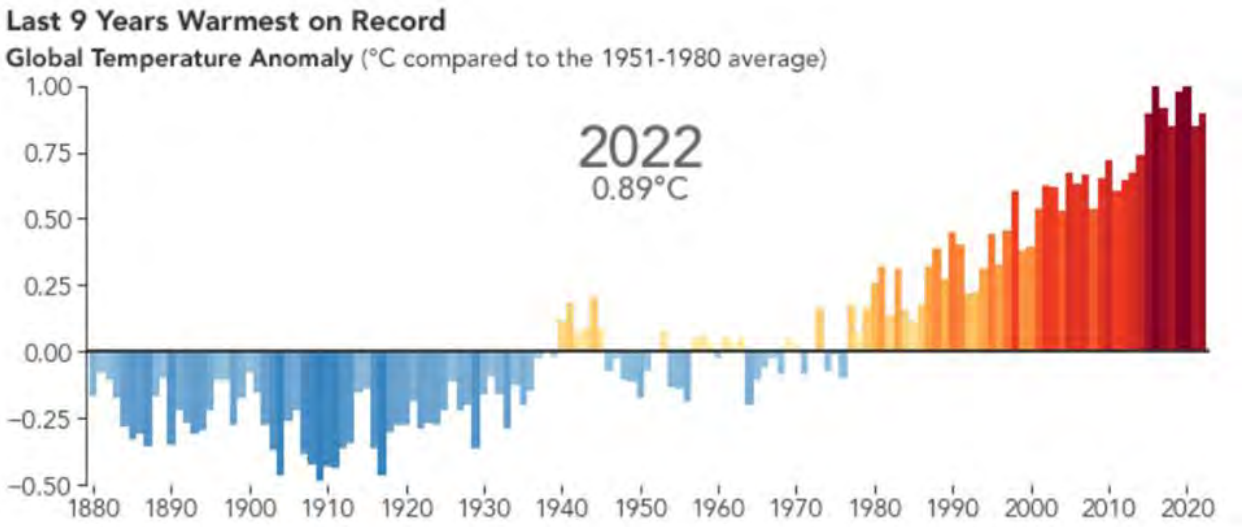

Figure 1-74. Rising Average Atmospheric Temperatures (global temperature anomaly)
Source: NASA Earth Observatory

Let us briefly examine one GYE climate-vulnerable species in particular, and the web of living things related to it. The subalpine species known as whitebark pine (*Pinus albicaulis*) (**Figure 1-75)** is one of the five-needle pine species (related to five-needle-per-fascicle eastern and western white pines) that ecologists consider foundational (aka a "keystone species") in high elevations in the Northern Rockies and the Pacific Northwest.[143]

Figure 1-75. Field technicians examine cones of a whitebark pine
Source: Erin Shanahan, National Park Service

[143] National Park Service, Yellowstone National Park. 2018. Examining the Evidence: Climate Change. Retrieved online 5-11-2024 at: https://www.nps.gov/yell/learn/nature/climate-examine-evidence.htm.

In late 2022, the USFWS listed whitebark pine as a threatened species under the Endangered Species Act (ESA), concluding that it is likely to become endangered throughout its range in the foreseeable future. "As a keystone species of the West, extending ESA protections to whitebark pine is critical to not only the tree itself, but also the numerous plants, animals, and watersheds that it supports," said USFWS Regional Director Matt Hogan in announcing the listing on December 14, 2022.[144]

Whitebark pine is important to other indigenous plants and animals and the sub-alpine ecosystem. Its seeds furnish a nutritious, energy-packed food source for birds and mammals such as the Clark's nutcracker (**Figure 1-76**), red squirrel, and grizzly bear, while healthy stands of whitebark pine also help abate soil erosion by slowing runoff from snowmelt. The disease known as white pine blister rust – an invasive, exotic fungal pathogen – is the main threat to whitebark pine. Other interrelated threats include mountain pine beetle infestations, modified wildfire patterns, and a warming climate (warmer temperatures permit the beetle to reproduce more quickly[145]). As a consequence of these interconnected threats and stressors, by 2016, ecologists estimated that more than half of all standing whitebark pine trees in the American West had already died.[146]

Figure 1-76. Clark's nutcracker feeding on whitebark pine cones
Credit: Jen Hooke, National Park Service

[144] U.S. Fish and Wildlife Service (USFWS). 2022. Whitebark pine receives Endangered Species Act protection as a Threatened species: Significant threats continue to challenge this keystone species of the American West. Press Release, December 22. Accessed online on 5-11-2024 at: https://www.fws.gov/press-release/2022-12/whitebark-pine-receives-esa-protection-threatened-species.
[145] National Park Service, Greater Yellowstone Inventory and Monitoring Network. 2024. Whitebark Pine. Retrieved online on 5-11-2024 at: https://www.nps.gov/im/gryn/whitebark-pine.htm.
[146] Op. cit.

While the whitebark pine can occur in pure stands, it also intermingles in mixed stands with other subalpine, high-elevation conifers such as lodgepole pine, Engelmann spruce, and subalpine fir. What the seeds of these other species lack in caloric value compared to whitebark seeds, they make up in more reliable production from year to year. Whitebark seed production is more variable (less dependable). Yet the bigger seeds or nuts of whitebark pine contain more protein, fats, and carbohydrates, and thus bears seek them out when trying to fatten up in the fall before winter's long hibernation.[147]

However, reaching the sought-after whitebark seeds is challenging for ground dwellers like the grizzly; whitebark pine cones are "indehiscent," meaning that they do not split open on their own to scatter seeds when mature. Since adult grizzly bears tend not to climb trees, they rely on industrious red squirrels to harvest whitebark seeds from above and concentrate them in middens on the ground. And then, in the words of Cecily M. Costello and co-authors:

> Ignoring the furious chatter coming from the branches above, the bear will dig up the midden's precious whitebark pine cones, carefully extract their seeds with dexterous claws, lips, and tongue, and consume the bulk of the cache in one sitting. Ah, the benefits of being a griz![148]

Scientists have recognized the value of whitebark pine seeds in bear diets for a long time. The decline of this valuable food source because of climate change and related threats has led to concern and debate about what it signifies for the bear's future. However, at least some researchers express cautious optimism because "grizzly bears are superb generalists, inhabiting a myriad of biomes worldwide." If these seeds are unavailable, they are capable of shifting to other food sources.[149]

In general, as this century proceeds, a warmer climate in all of its manifestations, has great portent for the GYE, as for other ecosystems. It will result in myriad predictable and unpredictable, disruptive and cascading perturbations to many elements of the ecosystem. Most but not all of these effects on established organisms and ecological communities will be adverse or negative, will generate "losers" but also "winners," and will produce a number of surprises. In the field of environmental assessment that has emerged over the past half-century under the National Environmental Policy Act (NEPA) of 1970 – the preparation of Environmental Impact Statements (EISs) and the like – climate change is often considered the epitome of both a stressor and an outcome in cumulative impacts analysis, that is, assessing the effects of actions added to and interacting with the effects of many other actions, and these net effects are notoriously difficult to predict with precision or accuracy.

[147] Cecily M. Costello et al. 2015. How Important is Whitebark Pine to Grizzly Bears? *Yellowstone Science*. 23(2): 12-16. Available online at: https://www.nps.gov/yell/learn/how-important-is-whitebark-pine-to-grizzly-bears.htm.
[148] Ibid.
[149] Ibid.

1.10 Beleaguered Wildlife Habitats and Open Space: A Primer

The adverse effects of encroaching development extend beyond the zone of impervious surfaces, pavement, and rooftops and penetrate into nearby natural habitats. The fact is that development disturbs adjacent natural habitat even without destroying or altering it directly with bulldozers and construction. Development can cause habitat fragmentation, that is, breaking up large, intact areas of natural habitat into smaller strips, shreds, and fragments.[150]

In such cases, these smaller, disparate, disconnected habitat bits and pieces may be too small to support viable populations of various wild flora and fauna, which are prevented from interacting and breeding due to development barriers like buildings, walls, fences, barbed wire, pavement, roads, and streets. Genetic diversity is lost and the risk of inbreeding and reduced survival fitness grows. Housing-induced habitat fragmentation and perturbation facilitate the introduction of exotic or invasive species.[151] Due to "edge effects", "patch-size effects," and "isolation effects," fragmentation is accompanied by biodiversity impoverishment and species loss, of both wild plants and wild animals.[152]

It is estimated that about one-third of new houses in the United States are now constructed in undisturbed natural habitats.[153] Roads connecting newly built residential subdivisions and commercial development break up the landscape and create hazards and barriers through wildlife home ranges.[154] As any motorist knows from observing the carnage of roadkill, paved roads and streets are deathtraps for hapless vertebrates: mammals, reptiles, amphibians, and even some birds. An estimated one million animals are killed on American roads every day.[155] Roadkill (**Figure 1-77**) is now the leading cause of vertebrate mortality in the U.S. and it is a major and growing cause of direct wildlife mortality in the GYE.

Anthropogenic noise from cars, trucks, and motorcycles, railroads, airport takeoffs and landings, compressors, factories, oil and gas exploration and development, and even amplified music from loudspeakers encroaches deeply into natural habitats and adversely affects wildlife through behavioral disruption, acoustic masking, and increased stress

[150] The Wildlife Society. Fact Sheet – Wildlife Habitat Fragmentation. Available at: http://wildlife.org/wp-content/uploads/2014/05/Wildlife-Habitat-Fragmentation.pdf.
[151] V.C. Radeloff, R.B. Hammer, and S. I. Stewart. 2005. Rural and Suburban Sprawl in the U.S. Midwest from 1940 to 2000 and Its Relation to Forest Fragmentation. *Conservation Biology*. 19(3): 793-805.
[152] Ibid.
[153] Radeloff, V. C., R. B. Hammer, S. I. Stewart, J. S. Fried, S. S. Holocomb, and J. F. McKeefry. 2005. The wildland-urban interface in the United States. *Ecological Applications* 15:799-805.
[154] Carroll, C., R. F. Noss, P. C. Paquet, and N. H. Schumaker. 2004. Extinction debt of protected areas in developing landscapes. *Conservation Biology* 18:1110-1120.
[155] Marc Bekoff. 2010. Animals and cars: One million animals are killed on our roads every day. *Psychology Today*. Accessed online 7-13-19 at: https://www.psychologytoday.com/us/blog/animal-emotions/201007/animals-and-cars-one-million-animals-are-killed-our-roads-every-day.

response.[156] One recent study found that human noise doubled background sound levels in a majority of our nation's protected natural areas, caused a 10-fold or greater increase in noise in 21 percent of these areas (surpassing noise levels known to interfere with human visitor experience), and significantly impaired habitats of endangered species.[157]

Figure 1-77. Elk Roadkill in the GYE
Photo credit: Holly Pippel

In a 2010 paper in the *Proceedings of the National Academy of Sciences* entitled, "Housing growth in and near United States protected areas limits their conservation value," the authors noted that protected areas are: "crucial for biodiversity conservation because they provide safe havens for species threatened by land-use change and resulting habitat loss." However, the effectiveness of protected areas in the United States is threatened by rural sprawl and housing development in particular. The study's findings show that housing development in

[156] M. Brittingham. Noise impacts to wildlife: A review of pertinent studies. Department of Ecosystem Science and Management, Penn State University. Available online at: http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20028837.pdf; Francis, C., C. Ortega, and A. Cruz. 2009. Noise Pollution Changes Avian Communities and Species Interactions. *Current Biology* 19:1415-1419; National Park Service. 2018. Effects of Noise on Wildlife. Available at: https://www.nps.gov/subjects/sound/effects_wildlife.htm.

[157] Rachel T. Buxton, Megan F. McKenna, Daniel Mennitt, Kurt Fristrup, Kevin Crooks, Lisa Angeloni, and George Wittemyer. 2017. Noise pollution is pervasive in U.S. protected areas. *Science*. Vol. 356, Issue 6337, pp. 531-533.

close proximity may severely limit the ability of protected areas to serve as a modern "Noah's Ark." The authors found that between 1940 and 2000, 28 million housing units were built within 50 km of protected areas in the United States, and 940,000 homes were even constructed on private inholdings within national forest boundaries.[158]

Further, they found that in the 1990s, housing built within 1 km of protected areas grew at a decadal rate of 20 percent, outpacing the national average of 13 percent. If these trends continue over the long term, another one million housing units would be built within 1 km of protected areas by 2030 (and 17 million housing units within 50 km), greatly reducing their value for wildlife and biodiversity conservation. The habitats protected as national parks, national wildlife refuges, national wilderness areas, and national forests are increasingly isolated spatially in an increasingly fragmented national landscape. In sum, protected areas in America, "are thus threatened similarly to those in developing countries. However, housing growth poses the main threat to protected areas in the United States whereas deforestation is the main threat in developing countries."

Urban expansion, of course, is not merely an American or a North American phenomenon; it is a global one. And globally, urban expansion is also driven by population growth, among other factors, but unsurprisingly, population's role in driving expansion and sprawl varies from continent to continent, region to region, and country to country. For example, population growth contributes to urban expansion more in North America than in Europe,[159] which has very low rates of population growth compared to Canada and the United States. Likewise, urban population growth is more closely related to urban expansion in Africa and India (both of which still experience rapid to very rapid population growth), than in China, where population growth gradually slowed, stopped, and has now reversed, and GDP growth is a greater factor in urban expansion.[160]

Across the world, scholars and planners widely regard population growth as one of the most important factors driving "land take" and urban land expansion, along with income growth (higher GDP per capita), increased transport accessibility, weak or inadequate planning, and subsidies encouraging land consumption and automobile use.[161]

[158] Volker C. Radeloff, Susan I. Stewart, Todd J. Hawbaker, Urs Gimmi, Anna M. Pidgeon, Curtis H. Flather, Roger B. Hammer, and David P. Helmers. 2010. Housing growth in and near United States protected areas limits their conservation value. *Proceedings of the National Academy of Sciences*. 107 (2): 940-945.
[159] Karen C. Seto, Michail Fragkias, Burak Güneralp, Michael K. Reilly. A Meta-Analysis of Global Urban Land Expansion. 2011. *PLoS One*. Vol. 6, Issue 8, August.
[160] Ibid.
[161] Alice Colsaet, Yann Laurans, and Harold Levrel. What drives land take and urban land expansion? A systematic review. *Land Use Policy*. 79 (2018): 339-349.

Recognition by scholars that population growth is a major (not the only) driver of urban land expansion and sprawl is sharply at odds with the way the news media and anti-sprawl activists in the United States have tended to portray the causes of sprawl. The news media and anti-sprawl activists have chosen to accept that rapid, unending U.S. population growth on the order of 20 to 30 or more million new residents per decade is a given and a fait accompli. They have no intent of questioning or challenging it.

Thus, since they want to convince Americans that something can still be done to halt or slow sprawl substantially in spite of never-ending U.S. population growth, they tend to downplay or minimize population's importance as a causal factor in sprawl. In their efforts to publicize sprawl to the American public and enlist support for anti-sprawl measures – e.g., "smart growth" policies, higher residential densities, multifamily housing (apartments and condominiums), mixed land uses and zoning, and infill that eliminates existing urban open space (such as golf courses) – they reserve their criticism for "low-density sprawl," essentially giving a pass to other new development on the urban periphery, as long as it is not low-density, even though it still permanently devours rural land and wildlife habitat.

According to the World Wildlife Fund: "Habitat loss poses the greatest threat to species. The world's forests, swamps, plains, lakes, and other habitats continue to disappear as they are harvested for human consumption and cleared to make way for agriculture, housing, roads, pipelines and the other hallmarks of industrial development."[162] The United States is home to more than 1,300 species and sub-species of plants and animals formally listed as federally endangered or threatened by the federal government (specifically, by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service).[163] Most of these are seriously harmed by ever-expanding sprawl and ever-encroaching development of one form or another that modifies, degrades, or eliminates the habitats they need to survive.

A school teachers' guide explains the process that steals habitats and puts species at risk:

> As the human population increases, cities, farms, ranches, factories, and shopping malls grow larger and expand into the wilderness….This leaves less habitat for animals and plants. Many of them cannot survive in other places. Their populations drop, and they become in danger of extinction.[164]

[162] World Wildlife Fund. No date. Losing their homes because of the growing needs of humans: Habitat loss is probably the greatest threat to the variety of life on this planet today. Retrieved online on 5-12-2024 at: https://wwf.panda.org/discover/our_focus/wildlife_practice/problems/habitat_loss_degradation/.
[163] U.S. Environmental Protection Agency (EPA). 2024. Learn More About Threatened and Endangered Species. Accessed online 5-12-2024 at: https://www.epa.gov/endangered-species/learn-more-about-threatened-and-endangered-species#.
[164] Desert Museum. "Endangered and Threatened Species of the Sonoran Desert Region." Desert Discovery Class Teacher Information ©2000, revised 2008 ASDM

The upshot is that habitat loss imperils wildlife much more than other factors such as pollution, toxics, invasive species, road mortality, overhunting, or poaching. A 2019 study by scientists with Conservation Science Partners for the Center for American Progress identified urban, agricultural, energy, and transportation "stressors" as the major causes in the loss and fragmentation of natural habitat in the lower 48 states.[165] Population growth exacerbates each of these factors. For example, more people need more farmland to cultivate the crops that become the food that feed those additional numbers. More people require more aggregate energy production to meet more aggregate consumption, hence more land is needed for petroleum exploration and development, access roads, pipelines, coal mines, wind farms, solar arrays, and so forth.

The Conservation Science Partners study concluded that expansion and intensification of land uses in the U.S. resulted in a steady, inexorable loss of natural areas between 2001 and 2017. In these 16 years alone, more than 24 million acres of natural lands and habitats were permanently modified or lost to development, at an average of 1.5 million acres per year. Just how enormous this loss is can be understood by comparing it to the areas of some of America's largest, most revered national parks, our "crown jewels." The natural habitats lost in just 16 years were equivalent in size to almost nine Grand Canyon National Parks, more than 10 Yellowstone NPs, or 49 Great Smoky Mountains NPs.

The urban stressor accounted for 57 percent of all the natural lands lost during the 16-year study period. Thus, urban sprawl devours more natural habitat than all other major causes of habitat loss combined.

1.11 Rejuvenating the Human Spirit: Physiological and Psychological Benefits of Nature and National Parks

Open space, national parks, greenery, natural areas – including wetlands, riparian corridors, farmland, beaches, rivers, lakes, the ocean, fields and forests – provide demonstrable mental and physical health benefits. They have proven to be preventative measures that can actually lower health care costs and reduce the need for health interventions. Exploring or even just gazing upon natural areas – such as a swamp or mangrove-fringed estuary next to a city, or a national park with wilderness such as Yellowstone – gives human beings a sense of perspective, continuity in a changing world, spiritual renewal, well-being, and a feeling of harmony with the world around us. The presence of open space within and adjacent to our urban areas (**Figure 1-78**) – and the assurance that this open space will outlast us – serves to counter-balance the stress and strain of modern life.

[165] Conservation Science Partners. 2019. Loss and fragmentation of natural lands in the conterminous U.S. from 2001 to 2017. Available online at: https://www.csp-inc.org/public/CSP%20Disappearing%20US%20Exec%20Summary%20011819.pdf.

Figure 1-78. Central Park Has Been Called a "Green Oasis" in New York City

Contact with nature and open space provides both physiological and psychological benefits. Research on the physiological benefits of open space has centered on how direct or indirect (vicarious) experience with vegetated and/or natural landscapes reduces stress, and anxiety.[166] A series of studies spanning nearly 20 years in the seventies and eighties linked photo simulations of natural settings to reduced stress levels as measured by heart rate and brain waves. One study revealed that subjects experienced more "wakeful relaxation" in response to slides showing vegetation only and vegetation with water compared to urban scenes without vegetation. These data were corroborated by attitude measures which indicated lower levels of fear and sadness when experimental subjects observed nature-related slides, as opposed to urban slides.[167] In studies of hospital patients, recovery was faster, there were fewer negative evaluations in patient reports, and there was less use of anesthetic medication among post-surgery patients with views of exterior greenery than among control group patients with views of buildings.[168]

[166] Rubenstein, N.R. The Psychological Value of Open Space. Chapter 4 in *The Benefits of Open Space*. The Great Swamp Watershed Association. 1997. Available on the World Wide Web at: http://www.greatswamp.org/publications/rubinstein.htm.
[167] Ulrich, R. 1979. Visual landscapes and psychological well-being. *Landscape Research*, 4(1): 17-23.
[168] Ulrich, R. 1983. Aesthetic and affective response to natural environment. Chapter 3 in I. Altman, & J. F. Wohlwill (Eds.), *Human Behavior and Environment*: Volume 6 (pp. 85-126). New York: Plenum Press; Ulrich, R. 1984. Views through a window may influence recovery from surgery. *Science*, 224, 420-421.

In other research, breast cancer survivors who engaged in personally enjoyable and nature-related "restorative activities" showed dramatic effects on their cognitive process and quality of life.[169] At the end of three months, the experimental group showed significant improvements in attention and self-reported quality of life measures; they had begun a variety of new projects. Control group members, meanwhile, who had been given no advice regarding nature exposure activities, continued with deficits in measures of attention, had started no new projects, and had lower scores on quality of life measures. This research underscored that difference between nature as an amenity and as a human need. As one reviewer of the study observed:

> "People often say that they like nature; yet they often fail to recognize that they need it...Nature is not merely 'nice.' It is not just a matter of improving one's mood, rather it is a vital ingredient in healthy human functioning."[170]

There is an important distinction between nature as amenity and nature as need. As one book affirms:

> "Viewed as an amenity, nature may be readily replaced by some greater technological achievement. Viewed as an essential bond between human and other living things, the natural environment has no substitutes."[171]

While there are many anecdotal reports linking the natural environment or open space to everything from increased self-esteem to stress reduction, there are few studies attempting to categorize the many phrases used to identify the worth of a walk in the woods or a day bird-watching beside a marsh.[172] Few studies track long-term longitudinal effects on changed attitudes and behavior. While it is difficult to characterize and quantify the long-term, intangible manner in which lives are modified, it is easy to acquire narrative accounts about the effect of a favorite overlook, trail, or patch of woods on one's psyche. One of the best known of such testimonials is from pioneering naturalist-conservationist John Muir:

> "Climb the mountains and get their good tidings. Nature's peace will flow into you as sunshine flows into trees. The winds will blow their own freshness into you, and the storms their energy, while cares will drop away from you like the leaves of Autumn."[173]

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[169] Cimprich, B. E. 1990. Attentional fatigue and restoration in individuals with cancer. Unpublished Doctoral Dissertation, University of Michigan.

[170] Kaplan, S. (1992). The Restorative Environment: Nature and human experience. In D. Relf (ed.), *The Role of horticulture in human well-being and social development: A National Symposium* [Proceedings of Conference Held 19-21 April 1990, Arlington, VA] (pp. 134-142). Portland, OR: Timber Press.

[171] Kaplan, R., & Kaplan, S. (1989). *The Experience of nature: A Psychological perspective*. New York: Cambridge University Press.

[172] Op. cit. Footnote #48, Rubenstein.

[173] John Muir. *The Mountains of California*. First published in 1894.

Natural settings are unparalleled in their ability to furnish solitude, privacy, and tranquility. They also have "existence value," that is, they provide worth to society in the knowledge that they are simply *there* and to the very idea that we *could* get away into them, if we so chose; this is a value in and of itself, which allows for a psychological "time-out" and a sense of wellbeing.

America's national parks are often said to symbolize our "crown jewels" or the preserved pinnacles of our nation's natural beauty, heritage, and green spaces; they are claimed to represent "America's best idea," one that did indeed set an example for the rest of the world to follow ever since the creation of Yellowstone National Park in 1872, more than a century and a half ago. Famed PBS documentary filmmaker Ken Burns named his six-part, Emmy Award-winning 2009 television documentary miniseries on the national parks "The National Parks: America's Best Idea."

Yet there is a natural tension or paradox related to public use and enjoyment versus preservation of the wild character of our beloved national parks. This was recognized even a century ago in the early days of the National Park Service, the federal agency in the Department of the Interior created in 1916 to oversee management of the national park system by trained, dedicated professionals. The utilitarian principle of "highest and best use" or the "greatest good for the greatest number" of publicly-owned natural resources and lands might be interpreted to mean celebrating and promoting ever-increasing numbers of visitors who get to enjoy a park, albeit under crowded conditions (**Figure 1-79**) that may tarnish the experience for some diehard lovers of solitude.

Figure 1-79. Summer crowding at Artist Point Overlook in Yellowstone Canyon
Source: Jacob W. Frank, National Park Service

The tension between the competing and contrasting utilitarian and preservationist philosophies of public lands and national parks management famously came to a head in the first decade of the 20th century in the struggle over the fate of Yosemite National Park's Hetch Hetchy Valley in California's Sierra Nevada Range. Booming San Francisco wished to build a water supply dam and reservoir in the valley to meet its burgeoning demand for water. This proposal was adamantly opposed by preservationists, led by Sierra Club co-founder John Muir, and ardently supported by utilitarians such as Gifford Pinchot, appointed by President Teddy Roosevelt as the first chief of the U.S. Forest Service. The utilitarians and Pinchot prevailed in that battle, but Muir and the preservationists generally won the war against wanton natural resource exploitation and development within national parks.

Yet in soliciting public funding for management and maintenance, NPS and national park supporters must be able to show Congress that parks are popular and being used. If a park benefits just a few "elitist" users, such as a handful of solitude-seeking, self-propelled, ultra-fit backcountry skiers (**Figure 1-80**), does it merit spending from the public purse and protection from developers? Or would the public be better served if roadless backcountry were opened up to many times more users by building a road, or to resource extraction that would provide, say, "clean-burning" natural gas to city-dwellers in an era of rising concern over where energy is going to come from? If the U.S. population and the population of the 20-county GYE region continue to grow as they have over the past 50 years, resource and user-group competition and conflicts will inevitably intensify, and the ability to preserve the GYE's iconic wilderness and wildlife for posterity will shrink accordingly.

Figure 1-80. Winter solitude in Yellowstone's backcountry.

Would this image convey a setting with greater value to society if it instead showed 50 skiers enjoying the snow and scenery if not solitude?

The July 2024 national and regional (ID-MT-WY) surveys[174] by Rasmussen Reports and NumbersUSA of likely voters conducted for this study on sprawl in the GYE found that the vast majority of them recognize the value of nature and open space for their emotional well-being. The survey of 1,128 likely U.S. voters asked:

> Do you feel an emotional or spiritual uplift from time spent in natural areas such as forests, wetlands, meadows, and mountains?
> 74% Yes
> 13% No
> 13% Not sure

Nearly three-quarters of the national electorate feels an emotional or spiritual uplift from being in natural areas. So does an even higher percentage (86%) of likely ID-MT-WY voters:

> Do you feel an emotional or spiritual uplift from time spent in natural areas such as forests, wetlands, meadows, and mountains?
> 86% Yes
> 8% No
> 6% Not sure

Two other survey questions are noteworthy in this regard. Among national voters:

> Where Do You Live?
> 30% Urban
> 49% Suburban
> 20% Rural
> 1% Not sure
>
> Prefer To Live?
> 26% Urban
> 37% Suburban
> 34% Rural
> 3% Not sure

Note that while 20 percent of respondents say they actually live in a rural area, 34 percent say would prefer to live in a rural area, suggesting that, on the whole, many Americans yearn for more rural settings and contact with nature in their day-to-day lives.

[174] Op cit. Note 4.

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2. FACTORS IN GREATER YELLOWSTONE ECOSYSTEM SPRAWL AND HABITAT LOSS

Over the past few decades, dozens of diverse factors have been suggested as causes of America's relentless, unending urban sprawl, defined here as the expansion of urban or developed land at the expense of rural land, including open space, wildlife habitat, and farmland (e.g., all agricultural lands including cropland, pasture, rangeland, ranchland, and private woodlands).

1. One factor is population growth.
2. All the other factors combine to increase per capita land consumption – which is the same as decreasing population density on developed or urbanized lands.

This study examines the relative importance of those two overall factors in the context of the 20 counties in Idaho, Montana, and Wyoming that comprise the Greater Yellowstone Ecosystem (GYE)

2.1 SPRAWL DEFINED

In colloquial speech, the word "sprawl" is not a precise term. But we do indeed use the term "Overall Sprawl" in a precise way in this study – it is the amount of rural land (aka open space) converted to developed land, or as is sometimes lamented, permanently "lost" to development. This rural land is either farmland, wildlife habitat, or both, but rarely neither. Even lands that appear to be barren wastelands usually support living communities, or "biota" in the parlance of biologists and ecologists. Both deserts and wetlands (e.g., marshes, swamps, fens, bogs, muskegs, mudflats, swales) were at one time dismissed as "useless," but now we know better.

2.2 OUR DATA SOURCES

Fortunately, we can measure or quantify the amount of Overall Sprawl that takes place over time because of a painstaking, comprehensive inventory process conducted by a federal agency concerned with counting and conserving the nation's productive agricultural land base: the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture (USDA).

For many decades since its establishment during the 1930s Dust Bowl, the NRCS was known as the Soil Conservation Service, or SCS. More than half a century ago, the lead author of this study, and his father, got to know quite well the SCS agent in Wetzel County, West Virginia. SCS agent Noel Cochran provided us with capable technical advice concerning

reforestation, soil conservation, landscape management, and habitat restoration on our 90-acre farm in the hilly Appalachian Plateau countryside of the Mountain State. He even helped to ensure that a natural gas company clearing trees along a right-of-way across our property to construct and lay a new gas pipeline provided mitigation in the form of a pond constructed in a hollow, after their careless tree clearing destabilized a steep slope caused a landslide.

In inventories conducted every five years since 1982, NRCS has estimated county-level changes in the areal extent or acreage of various categories of non-federal lands. These National Resources Inventories or NRIs now extend for 35 years, from 1982 to 2017. The next NRI covering up through 2022 will probably become available to the public in 2025.

Each NRI contains a Table 1 and a Table 2 (in addition to other tables). Table 1 compiles and classifies the surface area of 49 states (only Alaska is not included) according to the following basic categories: Federal Land, Water Areas, and Non-Federal Land. Non-Federal Land is further subdivided into Developed and Rural. The top row of Table 1 always looks like this:

State	Year	Federal land	Water areas	Non-Federal Land			Total surface area
				Developed	Rural	Total	

Table 2 then examines in greater detail the land cover/use of non-federal rural land. Here the categories are Cropland, Conservation Reserve Program (CRP) land, Pastureland, Rangeland, Forest land, and Other rural land. The top row of Table 2 for each state always resembles this:

State	Year	Cropland	CRP land	Pastureland	Rangeland	Forest land	Other rural land	Total rural land

Available NRI Developed Land estimates now span an uninterrupted 35-year period from 1982-2017 in seven 5-year intervals (1982-1987, 1987-1992, 1992-1997, 1997-2002, 2002-2007, 2007-2012, 2012-2017). In Table 1, these estimates quantify how much rural land was converted into developed or built-up land over these discrete, sequential time intervals, as well as over the 35-year time period in its entirety.[175]

The NRI covers the entire surface area (both land and water) of the United States, except Alaska, including 49 states, Puerto Rico, the U.S. Virgin Islands, and certain Pacific Basin

[175] U.S. Department of Agriculture. 2020. *Summary Report: 2017 National Resources Inventory*, Natural Resources Conservation Service, Washington, DC, and Center for Survey Statistics and Methodology, Iowa State University, Ames, Iowa. 123 pages. https://www.nrcs.usda.gov/sites/default/files/2022-10/2017NRISummary_Final.pdf

islands. The sample includes all land ownership categories, including, as noted, federal lands (e.g., national parks, national wildlife refuges, national forests, Bureau of Land Management lands, Department of Defense military installations), although NRI data collection activities have historically focused on non-federal lands.

Sampling is conducted on a county-by-county basis, using a stratified, two-stage, area sampling scheme. The two-stage sampling units are nominally square segments of land and points within these segments. The segments are typically half-mile-square parcels of land equal to 160-acre quarter-sections (a section is a square of territory one mile on each side, and comprising one square mile or 640 acres in area) in the Public Land Survey System, but there are a number of exceptions in the western and northeastern U.S. Three specific sample points are selected for most segments, although two are selected for 40-acre segments in irrigated portions of some western States, and some segments originally contained only one sample point.[176]

The 1997 NRI sample contained about 300,000 sample segments and 800,000 sample points (**Figure 2-1**). Whereas the NRI was conducted every five years up to 1997, an annual or continuous approach was begun in 2000. Each year a subset of between 71,000 and 72,000 segments from the 1997 sample is selected for observation. The subset is selected using a "supplemented panel rotation" design, meaning that a "core panel" of about 40,000 segments is observed each year along with a different supplemental or rotation panel chosen for each year.

Figure 2-1. Diagram of Hypothetical Landscape with Three Fixed Sample Points
Source: U.S. Department of Agriculture. 2020. *Summary Report: 2017 National Resources Inventory*, Natural Resources Conservation Service, Washington, DC, and Center for Survey Statistics and Methodology, Iowa State University, Ames, Iowa. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/results/

[176] Ibid.

The NRI survey system uses points as the sampling units rather than farms or fields, because land use and land unit boundaries often change in some parts of the country. Utilizing points has allowed the survey process to generate a database with dozens of factors or data elements that are properly correlated over many years. Thus, analyses and inferences based on these data are using proper combinations of longitudinal data.[177]

Data for the initial 1982 NRI were collected by thousands of field staff of the Soil Conservation Service (SCS – predecessor agency to NRCS), whose efforts were supplemented by contractors and employees of other agencies working under SCS supervision. Data collection began in the spring of 1980 and ran for more than two years, finishing in the autumn of 1982. For the 1987 NRI, data were also collected by teams of trained personnel. Remote sensing techniques (via aircraft or satellite) were used to update 1982 conditions for about 30 percent of the sample sites. Reliance upon remote sensing increased during the 1990s. Beginning in 2000, special high-resolution imagery was obtained for each NRI sample site.[178]

In 2004, NRCS established Remote Sensing Laboratories (RSLs) in Greensboro, NC; Fort Worth, TX; and Portland, OR. These three labs were designed, equipped, and staffed to take advantage of modern geospatial technologies, enabling efficient collection and processing of NRI survey data. The RSLs are now staffed with permanent employees whose full-time job is NRI data collection and processing.[179]

A number of quality control and quality assurance (QC/QA) processes are conducted by NRCS and contract staff as well as by the Statistical Unit and NRCS resource inventory specialists. Many of these QC/QA processes are embedded within the survey software developed by NRCS and the Statistical Unit. The QC/QA processes ensure that differences in the data over time reflect actual changes in resource conditions, rather than differences in the perspectives of two different data collectors, or changes in technologies and protocols.

One of the special features of the NRI is its genuine longitudinal nature, that is, its reliability and consistency through time, so that users of this dataset can be confident that, for example, differences in the area of developed land shown for 2017, 1997, and 1982 accurately reflect true differences "on the ground" or in reality. Even though many operational features of the NRI survey program have evolved over the years, processes have been implemented to ensure that data contained within the 2017 NRI database are longitudinally consistent. Data collection protocols always include review and editing of historical data for the particular NRI sampling units being observed.[180]

[177] Ibid.
[178] Ibid.
[179] Ibid.
[180] Ibid.

As noted above, NRI's broadest classification divides all U.S. territory into three categories: federal land, water areas, and non-federal land. Non-federal land is further subdivided into developed and rural. Rural lands are then disaggregated still further into cropland, CRP land, pastureland, rangeland, forestland, and other rural land. In the present study we are primarily concerned with developed land, although we do take note of trends in the area of different types of farmland.

NRI's developed land category differs from that used by other federal data collection entities. While other studies and inventories emphasize characteristics of human populations (e.g., Census of Population) and housing units (e.g., American Housing Survey), for the NRI, the intent is to identify which lands have been permanently eliminated from the rural land base. The NRI Developed Land category includes: (a) large tracts of urban and built-up land; (b) small tracts of built-up land less than 10 acres in size; and (c) land outside of these built-up areas that is in a rural transportation corridor (roads, interstates, railroads, and associated rights-of-way).

Since 1982, the NRI has inventoried land use in all 3,100+ counties in the contiguous 48 states plus Hawaii. It does not, however, count population, and for that our study relies on U.S. Census Bureau population estimates by county. Thus, we can observe how the area of developed land and population size have changed over time in all 20 counties of the GYE, and how these two fundamental variables are correlated…or not (**Figure 2-2**).

Figure 2-2. Lead author Leon Kolankiewicz in front of a new subdivision in the Gallatin Gateway in Gallatin County, Montana.

This would be captured as Developed Land in the next iteration of the NRI, but not the 2017 inventory, because at that time it was still undeveloped rural land.

Photo credit: Todd Wilkinson

One of the main concerns about urban sprawl has been that it is replacing our nation's forests, wetlands, wildlife habitat, and prime farmland with subdivisions, new and expanded roads, strip malls, and business parks. As the NRCS expressed it in the 2007 NRI summary report, reviewing the 1982-2007 quarter-century:

> The net change of rural land into developed land has averaged 1.6 million acres per year over the last 25 years, resulting in reduced agricultural land, rangeland, and forest land. Loss of prime farmland, which may consist of agriculture land or forest land, is of particular concern due to its potential effect on crop production and wildlife.[181]

Nationwide, from 1982 to 2017, about 69,000 square miles (44,175,300 acres) – an area than Florida – of previously undeveloped, non-federal rural land was paved over to accommodate our growing cities and towns (**Figure 2-3**). The total amount of developed land was 72.1 million acres in 1982. By 2017, this had climbed to 116.3 million acres.

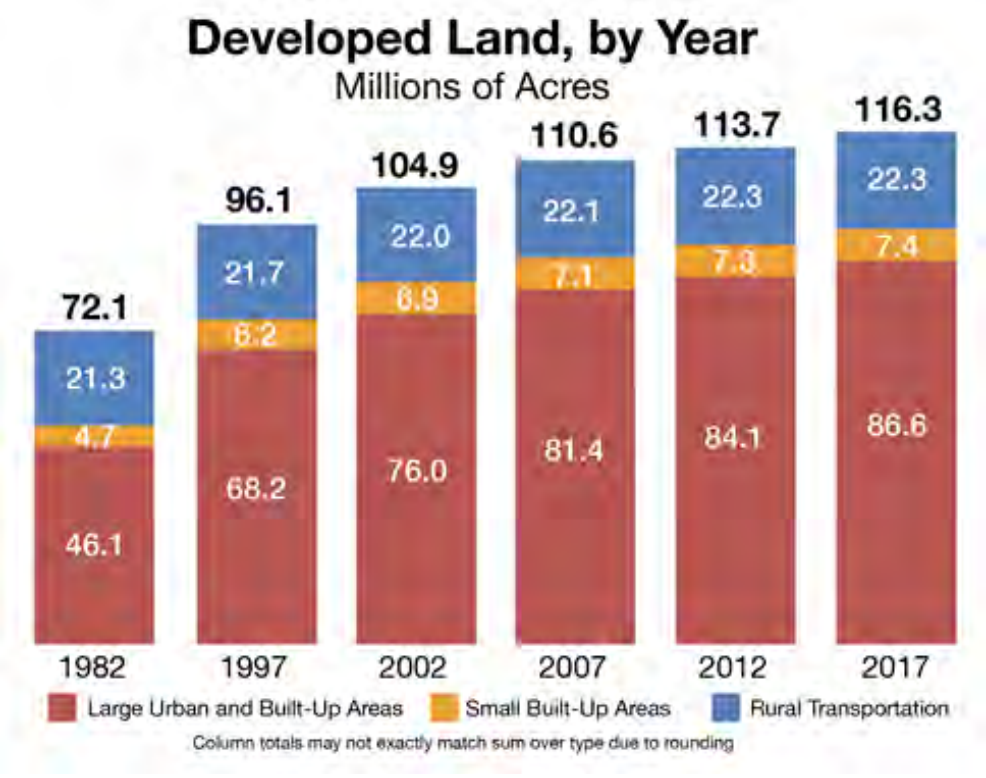

Figure 2-3. Cumulative Growth in Area of Developed Land Nationwide, 1982-2017
Source: *2017 National Resources Inventory, Summary Report*, p. 2-6.

Where did these developed lands come from? What types of rural land uses were converted into developed land? These are quantified in **Figure 2-4**, the sources of newly developed land, including cropland, pastureland, rangeland, forestland, and other rural lands.

[181] Natural Resources Conservation Service (NRCS). 2013. 2007 National Resources Inventory: Development of Non-Federal Rural Land. March.

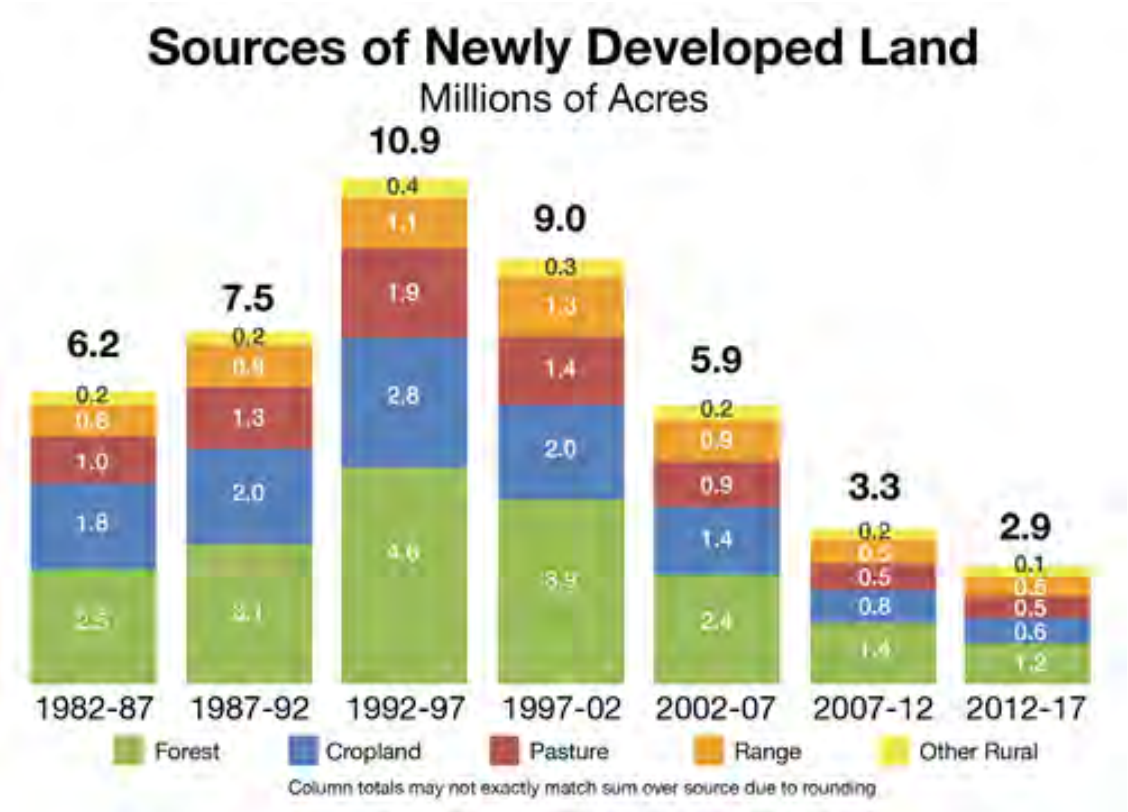

Figure 2-4. Sources of Newly Developed Land, 1982 to 2017

Source: *2017 National Resources Inventory, Summary Report*, p. 2-7.

Table 2-1 summarizes these sources of newly developed land in the United States over the entire 35-year study period. Approximately 19.1 million acres of forested lands were developed from 1982 to 2017, the largest single category. Croplands were in second place, with 11.4 converted into developed lands. Again, it should be emphasized that each of these land categories possesses value as either wildlife habitat, productive agricultural land, or both.

Table 2-1. Sources of Newly Developed Land in the United States, 1982-2017

Land Type	Millions of acres
Forest	19.1
Cropland	11.4
Pasture	7.5
Range	6.0
Other Rural	1.6
Total acreage	45.6

2.3 POPULATION GROWTH

A city, county, state, or country's population grows due to personal behavior – births (fertility) and in-migration – and because of local, state, and national governmental actions and policies. Looking more closely, the net increase (or decrease) in a place's population in any given time period (e.g., one year, one decade) is due to the number of births minus the number of deaths plus the number of in-migrants minus the number of out-migrants.

Table 2-2 shows population change (all population increases, with one exception) in the 20 counties enveloping the Greater Yellowstone Ecosystem (**Figure 2-5**) from the 1970 Census to the 2023 U.S. Census Bureau estimates. We chose 1970 because that was the year the first Earth Day was celebrated, and it's now more than half a century ago (54 years), so it seemed a fitting start date to chart long-term population growth in the GYE, given the environmental and wildlife conservation focus of this study. As noted above, the combined area of these counties is larger than that typically given for the GYE, which does not have set or formally established boundaries. It is important for the purposes of this study to include the entire GYE; the residents of these 20 counties may be regarded as residents and immediate neighbors of the GYE.

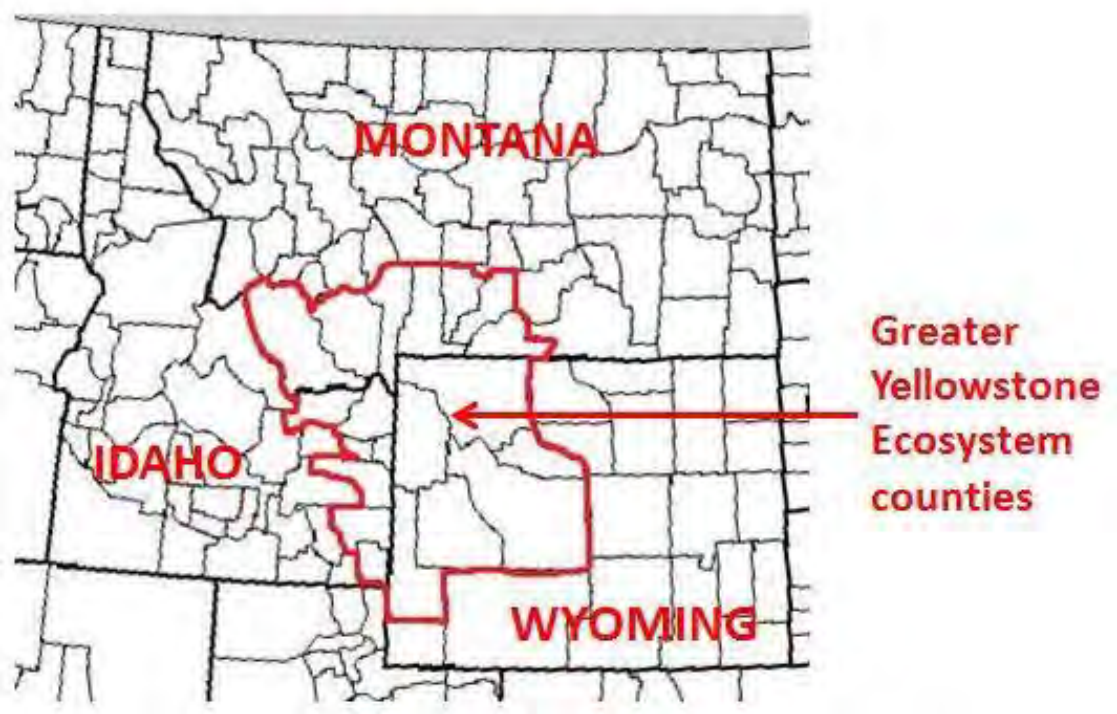

Figure 2-5. Boundaries of the 20 counties in Idaho, Montana, and Wyoming containing the Greater Yellowstone Ecosystem

Table 2-2. Population Change in the 20 GYE Counties from 1970 to 2023

County	1970 population	2023 population	Change, 1970-2023	Percent change, 1970-2023
Idaho				
Bear Lake	5,801	6,766	965	17%
Bonneville	51,250	131,366	80,116	156%
Caribou	6,534	7,219	685	10%
Clark	741	801	60	8%
Fremont	8,710	14,196	5,486	63%
Madison	13,452	54,547	41,095	305%
Teton	2,351	12,549	10,198	434%
Totals ID GYE Counties	**88,839**	**227,444**	**138,605**	**156%**
Montana				
Beaverhead	8,187	9,885	1,698	21%
Carbon	7,080	11,419	4,339	61%
Gallatin	32,505	126,409	93,904	289%
Madison	5,014	9,521	4,507	90%
Park	11,197	17,903	6,706	60%
Stillwater	4,632	9,173	4,541	98%
Sweet Grass	2,980	3,763	783	26%
Totals MT GYE Counties	**71,595**	**188,073**	**116,478**	**162%**
Wyoming				
Fremont	28,352	39,815	11,463	40%
Hot Springs	4,952	4,661	-291	-6%
Lincoln	8,640	20,880	12,240	142%
Park	17,752	30,735	12,983	73%
Sublette	3,755	8,969	5,214	139%
Teton	4,823	23,232	18,409	382%
Totals WY GYE Counties	**68,274**	**128,292**	**60,018**	**88%**
All GYE Counties	**228,708**	**543,809**	**315,101**	**138%**

In **Table 2-2**, it can be seen that the aggregate population of the 20 counties containing the entire GYE grew from 228,708 in 1970 to 543,809 in 2023, an increase of 315,101, or 138 percent. That is, the aggregate population more than doubled during these 53 years. The seven GYE counties in Montana increased by the most, on average, at 162 percent, while the six GYE counties in Wyoming increased the least of the three states, at 88 percent. The only county with a smaller population in 2023 than 1970 was Hot Springs County in Wyoming. Thus, only one of the 20 counties, or five percent, experienced negative population growth, which is much smaller than the national average of about one-third (35%) of counties in the U.S. as a whole which have undergone populations decline in recent decades.

The compound annual growth rate (CAGR), or exponential growth rate, of the 20 GYE counties over this 53-year period was 1.65%. CAGRs always seem unimpressive, but over time, seemingly modest rates can lead to a staggering increase in the numbers of anything, whether widgets or people. By way of comparison, the CAGR of the entire United States over this same time period, during which the U.S. grew from 203 million in 1970 to 335 million in 2023, was 0.95%. In other words, the aggregate population of the 20 GYE counties grew at a rate 74 percent faster than the country as a whole.

Nowadays, as a general rule throughout the United States, rapid population growth in a city, county, or state is likely to be the result of policies, incentives, and subsidies explicitly enticing businesses to build, expand or site their new facilities there and residents to relocate from elsewhere. In contrast, other fortunate "last best places" (**Figure 2-6**) like the GYE counties may face the opposite challenge, that of trying to discourage too many newcomers from settling in their midst, and of growing so fast or to such an extent that they begin to lose the very character or qualities, such as compact size, little traffic, few stoplights, good air and water quality, or easy access to the countryside, that made them so desirable in the first place.

Figure 2-6. Sign proclaiming the GYE city of Bozeman, MT as the "last best place"

Local and state governments can and often do create many unequivocal financial incentives or subsidies that encourage industry and people to move into a particular urban area. These include aggressive campaigns to persuade industries and corporations to move their factories, offices, headquarters, and jobs from another location, public subsidies for the infrastructure that supports businesses, tax breaks, expansion of water service and sewage lines into new areas, new housing developments and new residents, and general public relations campaigns that increase the attractiveness and "business friendliness" of a municipality to outsiders and the business community. Even without trying, a city may attract new residents just by maintaining amenities, good schools, low crime rates, pleasant parks, and a high quality of life, especially if the nation's population is growing significantly, as continues to be the case in America today.

Table 2-3 shows the population change in all 20 GYE counties from 1982 to 2017, the 35-year period of study, i.e., the time period for which there are NRI county-level data on developed land.

Table 2-3. Population Change in the 20 GYE Counties, 1982 to 2017

County	1982 population	2017 population	Change, 1982-2017	Percent change, 1982-2017
Idaho				
Bear Lake	7,385	6,023	-1,362	-18%
Bonneville	66,865	114,488	47,623	71%
Caribou	8,873	6,973	-1,900	-21%
Clark	831	879	48	6%
Fremont	11,080	13,122	2,042	18%
Madison	20,912	39,370	18,458	88%
Teton	3,185	11,445	8,260	259%
Totals ID GYE Counties	**119,131**	**192,300**	**73,169**	**61%**
Montana				
Beaverhead	8,674	9,450	776	9%
Carbon	8,342	10,680	2,338	28%
Gallatin	45,372	108,576	63,204	139%
Madison	5,820	8,291	2,471	42%
Park	13,568	16,386	2,818	21%
Stillwater	5,819	9,419	3,600	62%

County	1982 population	2017 population	Change, 1982-2017	Percent change, 1982-2017
Sweet Grass	3,305	3,676	371	11%
Totals MT GYE Counties	**90,900**	**166,478**	**75,578**	**83%**
Wyoming				
Fremont	38,492	39,818	1,326	11%
Hot Springs	5,982	4,686	-1,296	-1%
Lincoln	14,030	19,278	5,248	30%
Park	23,263	29,194	5,931	13%
Sublette	5,142	9,745	4,603	53%
Teton	10,519	23,384	12,865	24%
Totals WY GYE Counties	**97,428**	**126,105**	**28,677**	**29%**
All GYE Counties	**307,459**	**484,883**	**177,424**	**58%**

On average during these 35 years, the 20 GYE counties grew by a combined 58 percent, at a CAGR of 1.31%. By comparison, the entire country grew at a CAGR of 0.97% from 1982 to 2017. Thus, during the period of study, the 20 GYE counties grew at a CAGR 35 percent higher than the nation as a whole. Note that this is less of a discrepancy than in the entire 1970 to 2023 time span shown in **Table 2-2**, when the GYE grew at a rate 74 percent faster than the country as a whole. This would tend to make the findings of our study concerning the role of population growth in driving GYE sprawl rather conservative or cautious, because the population grew at a slower rate during our 35-year period of study than during the longer 53-year time frame of **Table 2-2.**

Throughout the study, we will also examine the most recent 15-year portion of the full 35-year study period to see how sprawl and its drivers are trending. **Table 2-4** displays population growth in the 20 GYE counties from 2002 to 2017.

Table 2-4. Recent Population Change in the 20 GYE Counties, 2002 to 2017

County	2002 population	2017 population	Change, 2002-2017	Percent change, 2002-2017
Idaho				
Bear Lake	6,219	6,023	-196	-3%
Bonneville	85,060	114,488	29,428	35%

County	2002 population	2017 population	Change, 2002-2017	Percent change, 2002-2017
Caribou	7,161	6,973	-188	-3%
Clark	948	879	-69	-7%
Fremont	12,029	13,122	1,093	9%
Madison	28,478	39,370	10,892	38%
Teton	6,849	11,445	4,596	67%
Totals ID GYE Counties	**146,744**	**192,300**	**45,556**	**31%**
Montana				
Beaverhead	9,018	9,450	432	5%
Carbon	9,714	10,680	966	10%
Gallatin	71,824	108,576	36,752	51%
Madison	6,935	8,291	1,356	20%
Park	15,676	16,386	710	5%
Stillwater	8,441	9,419	978	12%
Sweet Grass	3,617	3,676	59	2%
Totals MT GYE Counties	**125,225**	**166,478**	**41,253**	**33%**
Wyoming				
Fremont	36,015	39,818	3,803	11%
Hot Springs	4,743	4,686	-57	-1%
Lincoln	14,858	19,278	4,420	30%
Park	25,761	29,194	3,433	13%
Sublette	6,389	9,745	3,356	53%
Teton	18,837	23,384	4,547	24%
Totals WY GYE Counties	**106,603**	**126,105**	**19,502**	**18%**
All GYE Counties	**378,572**	**484,883**	**106,311**	**28%**

During the 15-year period from 2002 to 2017, the GYE population grew at a CAGR of 1.66%, somewhat faster than the CAGR of the overall 35-year period of 1.31%, meaning that the rate of population growth accelerated in recent years. During this same 2002-2017 time period, the United States grew at a CAGR of 0.81%, meaning that the GYE population was growing twice as fast as the country in general.

2.3.1 Sources/Causes of Population Growth

Quantifying or estimating the sources or causes of recent population growth in each of the 20 GYE counties in three states (Idaho, Montana, and Wyoming) would involve detailed demographic analysis (extensive number crunching and complex assumptions) beyond and outside the scope of this study. However, we have estimated the sources or causes of recent population growth in each of the three GYE states, which represent a first order approximation (i.e., rough approximate value) of the sources/causes of population growth in the GYE counties per se.

Figure 2-7. North Breccia Cliffs (11,007') in the Bridger-Teton National Forest, Wyoming

These 20 GYE counties together account for 15 percent of the population (544,000 of 3.7 million) and comprise 19 percent of the land area (61,693 of 328,422 square miles) of Idaho, Montana, and Wyoming, the 14th, 4th, and 10th largest states by total (land plus water) area, respectively, in the United States. These are large states with relatively small populations. By comparison, colossal California has about **ten times** the population of all three states combined crammed into about **half their combined land area,** meaning that California has a crude population density about **20 times** that of these three Northern Rockies states combined. (And in fact, even this comparison of crude population densities is somewhat misleading, because large swaths of California in its expansive deserts, rugged mountain ranges, and northern forests have very low human population density.)

Before delving into the details of each state's demographics, we must stress that federal immigration policies have indirectly further contributed to the overall region's population growth over and above the levels shown below. A large percentage of U.S.-born migrants to Idaho, Montana, and Wyoming have fled other Western states that have experienced many negative quality-of-life developments stemming from their own massive population growth. By way of example, **Table 2-5** shows the states sending the most people to Idaho in 2019. (Montana and Wyoming show very similar if not identical results.) All of these "sending states" are nearby Western states with high rates of population growth. All but Oregon are also states of high immigration (by raw numbers or rate of growth).

Table 2-5. Top Five Sending States to Idaho (2019)

Rank	State
1	California
2	Washington
3	Oregon
4	Utah
5	Arizona

Perhaps the greatest pressure on the future of the three GYE states is related to California having apparently reached some kind of tipping point after a century plus of extraordinary population expansion from just 1.5 million in 1900 to nearly 40 million residents today. Just since 1982, more than 2 million acres of California have been converted from farmland and natural habitat to developed land even as the state population continued its boom, until about a decade ago.

People fleeing California's extensively documented and heavily publicized socioeconomic and environmental problems – particularly the high cost of housing – are the largest single source of Idaho's newcomers, and likely Montana's and Wyoming's as well.

These three states, with their population densities of 24 residents per square mile (Idaho, 44th among the 50 states), 7.8 (Montana, 48th among the 50 states), and 6.0 (Wyoming, 49th among the 50 states), can look awfully alluring to Californians living at a density of 250 residents per square mile and seeking more elbow room, breathing space, and lower housing prices. As high levels of foreign immigration continued unabated into California in the past decade, nearly eight million Americans moved from California to other states from 2010 through 2021.

Even a tiny fraction of disgruntled Californians spilling into the GYE states can swamp efforts to preserve these states' character and sense of wide open spaces. Thus, their demographic destiny appears inextricably linked to the destiny of California, a state that Idaho residents, for one, overwhelmingly say they do not want to emulate. Bumper stickers and other signs with slogans such as "Don't Californicate Idaho" attest to their concerns.

Idaho

Foreign immigration accounted for approximately 133,000 (18%) of the 740,000 increase in Idaho's population from about 974,000 to 1.714 million over the 1982-2017 study time period.[182] This is based on growth in four groups of residents who would not have been in Idaho if not for foreign migration:

- Foreign-born Idaho residents in 2017 who arrived in the U.S. after 1982 and came directly to Idaho from abroad or via another state (75,000).
- Minors (under age 18) in 2017 who were born in the U.S. to post-1982 immigrants (38,000).
- Adults in 2017 who were born in the U.S. to post-1982 immigrants (14,000).
- Minors (under age 18) who are the U.S.-born grandchildren of post-1982 immigrants (6,000).

Taking into account all forms of migration into Idaho – both domestic and foreign – net migration (immigration minus emigration) accounted for 59 percent of its population growth from 1990 to 2019 and natural increase (births minus deaths) for 41 percent (**Figure 2-8**).

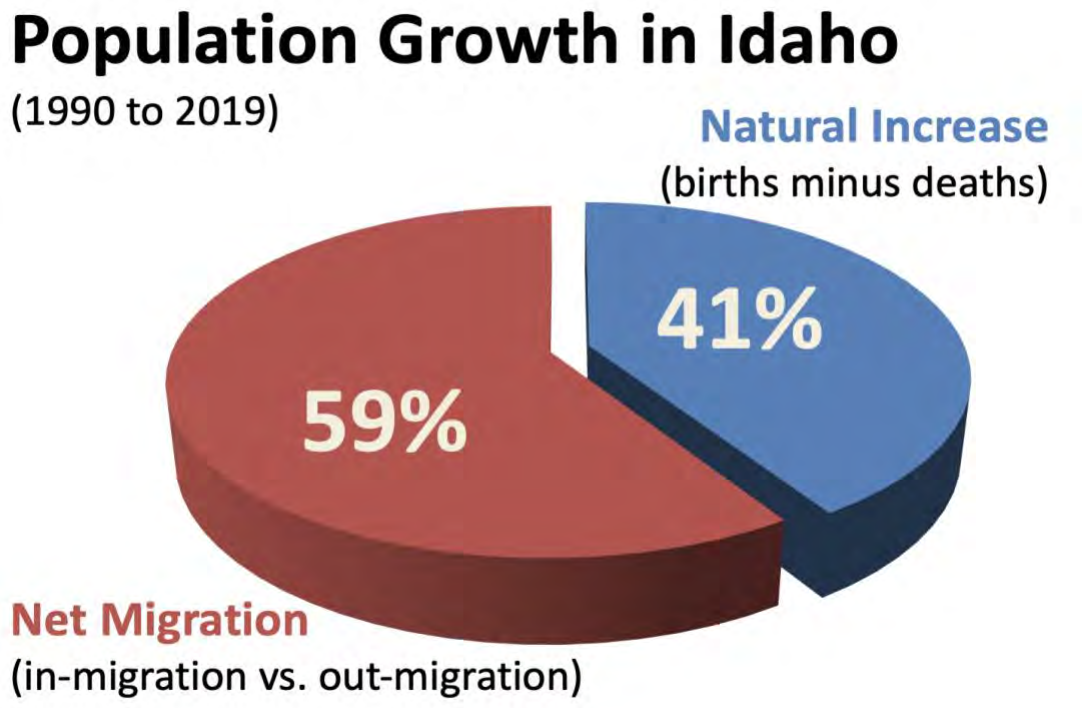

Figure 2-8. Sources of Idaho Population Growth, 1990 to 2019

[182] See Appendix H in this report for a detailed description of the methodology use to derive this estimate.

Montana

Foreign immigration accounted for 27,000 (10.7%) of the 253,000 increase in Montana's population from 801,000 to 1.054 million over the 1982-2017 study time period.[183] In total, using the same methodology as for Idaho above, we estimate there were 27,123 post-1982 immigrants, their children and grandchildren living in Montana in 2017. See Appendix H for a more detailed discussion.

Figure 2-9. Yellowstone River in Paradise Valley between Gardiner and Livingston, Montana, with mountains of the Custer-Gallatin National Forest behind

Wyoming

Foreign immigration accounted for approximately 23,800 (30.5%) of the 78,000 increase in Wyoming's population from 502,000 to 580,000 over the 1982-2017 study time period.[184] See Appendix H for a more detailed discussion.

[183] Ibid.
[184] Ibid.

Figure 2-10. Deep dusk settles over Wyoming's towering Grand Teton (13,775') and the glowing Snake River far below

Overall, for all three states combined, foreign immigration accounted for 183,800 (17%) of the aggregate population increase of 1,071,000 between 1982 and 2017.

Domestic and foreign migration together likely accounted for more than half the aggregate population growth in all three states combined. Residents of the three states are well aware of in-migration's enormous import for their current quality of life and future character, and are rather sharply opposed to it, gauging by the response to this question in the late July 2024 Rasmussen-NumbersUSA survey (Appendix E):

> The main source of Greater Yellowstone's population growth is people moving in from other states. Should local and state governments in Montana, Wyoming, and Idaho make it more difficult for people to move to the region from other states by restricting development?
>
> 68% Yes
> 17% No
> 16% Not sure

2.4 PER CAPITA DEVELOPED LAND CONSUMPTION

Per capita land consumption statistics are a useful way to understand the combined power of numerous land use and consumption choices that can lead to urban sprawl. See Appendices B and C for how this statistic is calculated.

When U.S. Census Bureau data show that per capita developed land consumption was 0.42 acre in 2017 in Gallatin County, Montana, it means that each resident was using or "consuming" somewhat more than one-third of an acre to furnish housing, work, retail, transportation, education, religious assembly, government, recreation, utilities, and all other urban needs. Because of the interconnected, interdependent nature of economies between counties and states – the flows and transport of raw materials, manufactured products, and labor (workforce) along transportation corridors such as the Interstate Highway System – some unknown percentage of the developed land in certain counties is supplying the needs and demands of resident of other counties. For example, a regional shopping mall or a large factory or workplace located in a given county may provide jobs and products for residents of other nearby or even distant counties. And this accounts for some of the variation observed in developed land per capita between counties.

In simplified form, the per capita developed land consumption of a county is determined by dividing all the developed acreage by the total number of county residents (obtained from the U.S. Census Bureau). The lower the per capita consumption number, overall, the more efficiently the population is using the land for urban or developed purposes.

2.4.1 Per Capita Developed Land Consumption in GYE Counties

Table 2-5 shows the change in per capita developed land consumption in the GYE's 20 counties from 1982 to 2017. On the whole, the average GYE resident "used" 1.12 acres of developed land in 1982 and 1.03 acres in 2017, for a decrease in per capita developed land consumption of nine percent. This value of 1.03 acre/resident is much higher per capita developed land consumption than that of the average American resident, which is about one-third of an acre per person.

On the other hand, it is relatively typical of more rural, smaller-population counties in the country, where there is a greater area of developed land per person than in urban areas. This does not necessarily mean that rural communities use land less efficiently than urban areas, but that smaller population counties have a certain amount of necessary facilities and infrastructure that do not decrease with smaller populations. That is, "economies of scale" are lost. In the entire state of North Dakota, for example, a relatively rural state with a smallish population (about one million in 2017) and a mostly fossil fuels extraction and

agriculture-based economy, the average per capita developed land consumption in 2017 was 1.4 acres, 40% larger than in the GYE counties.

One outlier or anomaly in **Table 2-6** is Caribou County in Idaho, where per capita developed land consumption increased markedly, by 246 percent, to 5.57 acre/person. Looking at raw data in the 2017 NRI spreadsheets, a spike in developed land happened primarily between 1987 and 1992, when the area of developed land jumped from an estimated 13,100 acres to an estimated 26,900 acres in just five years. During the same time period, the area of cropland in Caribou County also dropped precipitously, from 201,700 acres in 1987 to 155,300 acres in 1992. At the same time, the county's population was in overall decline; it went from 8,873 in 1972 to 6,973 in 2017 (**Table 2-4**), a decrease of 1,900 residents or 21 percent. We can only speculate as to what accounts for these anomalies, but they are rather unusual. Without knowing the particulars of what happened in Caribou County to account for this, in general, large construction or resource development projects could be responsible for cropland losses and developed land gains without concomitant permanent population increases in the same county.

Table 2-6. Per Capita Developed Land Consumption in GYE Counties – 1982 and 2017

County	Per Capita Developed Land Consumption – 1982 (acre)	Per Capita Developed Land Consumption -2017 (acre)	% Change in Per Capita Land Consumption, 1982-2017
Idaho			
Bear Lake	1.04	1.54	48%
Bonneville	0.42	0.37	-11%
Caribou	1.15	3.97	246%
Clark	5.42	5.57	3%
Fremont	1.26	1.22	-3%
Madison	0.40	0.36	-10%
Teton	0.88	0.93	5%
Montana			
Beaverhead	2.17	2.54	17%
Carbon	1.15	1.00	-13%
Gallatin	0.46	0.42	-9%

County	Per Capita Developed Land Consumption – 1982 (acre)	Per Capita Developed Land Consumption -2017 (acre)	% Change in Per Capita Land Consumption, 1982-2017
Madison	2.44	1.94	-20%
Park	0.74	0.85	15%
Stillwater	2.22	1.69	-24%
Sweet Grass	3.51	4.03	15%
Wyoming			
Fremont	2.95	3.09	5%
Hot Springs	0.80	1.49	86%
Lincoln	0.78	1.12	44%
Park	1.07	1.31	22%
Sublette	2.00	2.02	1%
Teton	0.72	0.95	32%
All GYE Counties	**1.12**	**1.03**	**-9%**

Table 2-7 shows recent changes (2002-2017) in per capita developed land consumption in the 20 GYE counties. Once again, there was a decline, from 1.14 to 1.03, or 10 percent. Examining the values of both Tables 6 and 7 indicates that during the entire 35-year period, per capita developed land consumption in the GYE rose during approximately the first half, reached a peak, and then began a gradual decline.

Table 2-7. Per Capita Developed Land Consumption in GYE Counties – 2002 and 2017

County	Per Capita Developed Land Consumption – 2002 (acre)	Per Capita Developed Land Consumption -2017 (acre)	% Change in Per Capita Land Consumption, 2002-2017
Idaho			
Bear Lake	1.45	1.54	7%
Bonneville	0.41	0.37	-11%

County	Per Capita Developed Land Consumption – 2002 (acre)	Per Capita Developed Land Consumption -2017 (acre)	% Change in Per Capita Land Consumption, 2002-2017
Caribou	3.84	3.97	3%
Clark	5.06	5.57	10%
Fremont	1.26	1.22	-4%
Madison	0.42	0.36	-16%
Teton	0.99	0.93	-7%
Montana			
Beaverhead	2.62	2.54	-3%
Carbon	1.02	1.00	-2%
Gallatin	0.44	0.42	-5%
Madison	2.12	1.94	-8%
Park	0.63	0.85	37%
Stillwater	1.80	1.69	-6%
Sweet Grass	3.79	4.03	6%
Wyoming			
Fremont	3.35	3.09	-8%
Hot Springs	1.24	1.49	20%
Lincoln	1.10	1.12	2%
Park	1.23	1.31	6%
Sublette	2.94	2.02	-31%
Teton	1.01	0.95	-6%
All GYE Counties	**1.14**	**1.03**	**-10%**

At a minimum, the per capita developed land consumption figure reflects the combined outcome of all the following individual and institutional choices and factors:

- Development
  - Consumer preferences for size and type of housing and yards
  - Developer preferences for constructing housing, offices and retail facilities
  - Governmental subsidies that encourage land consumption, and fees and taxes that discourage consumption
  - Quality of urban planning and zoning
  - Level of affluence
  - Size of the entire built-up urbanized land area comprised of non-residential land uses, such as industrial, institutional, government, commercial, etc.
- Transportation
  - Governmental subsidies and programs for highways, streets and mass transit
  - Consumer preferences favoring the mobility and flexibility offered by using private vehicles rather than public transit
  - Price of gasoline (cheap gas encourages sprawl)
- Quality of existing communities and ability to hold onto their residents
  - Quality of schools
  - Reality and perceptions concerning crime and personal safety
  - Ethnic and cultural tensions or harmony
  - Quality of government leadership
  - Job opportunities
  - Levels of pollution
  - Quality of parks, other public facilities and infrastructure
- Number of people per household
  - Marriage rate and average age for marriage
  - Divorce rate
  - Recent fertility rate
  - Level of independence of young adults
  - Level of affluence enabling single people to live separately

As noted above, states and counties with economies that are more oriented towards agriculture and/or extraction of raw materials and energy (e.g., mining, oil and gas development, and increasingly, large wind and solar farms) would also tend to have low population densities for any given amount of developed land. However, that development goes to support, underwrite, or accommodate – that is, is connected to – higher and denser human populations elsewhere in the country or the world.

Figure 2-11. Bison on divide between Slough Creek and Lamar River, Yellowstone National Park

Figure 2-12. Teton Range from Jackson Lake Lodge, Grand Teton National Park

2.5 POPULATION VERSUS CONSUMPTION

Table 2-8 compares change in population to change in per capita land consumption in the 20 GYE counties from 1982 to 2017. Across these 35 years, all GYE counties increased their combined population by 58 percent, while their aggregate per capita land consumption actually decreased by nine percent. While one of the two factors that drive urban sprawl grew in prominence, the other contracted, at least in aggregate for the GYE as a whole (when all 20 counties in three states are aggregated or considered together). It should be noted, however, that per capita developed land consumption did actually increase in 13 of the 20 GYE counties, more than half of them. All GYE counties in Wyoming increased per capita developed land consumption.

Table 2-8. Population Growth vs. Growth in Per Capita Developed Land Consumption in GYE Counties, 1982-2017

County	% POPULATION GROWTH, 1982-2017	% GROWTH IN PER CAPITA LAND CONSUMPTION, 1982-2017
Idaho		
Bear Lake	-18%	48%
Bonneville	71%	-11%
Caribou	-21%	246%
Clark	6%	3%
Fremont	18%	-3%
Madison	88%	-10%
Teton	259%	5%
Montana		
Beaverhead	9%	17%
Carbon	28%	-13%
Gallatin	139%	-9%
Madison	42%	-20%
Park	21%	15%

County	% POPULATION GROWTH, 1982-2017	% GROWTH IN PER CAPITA LAND CONSUMPTION, 1982-2017
Stillwater	62%	-24%
Sweet Grass	11%	15%
Wyoming		
Fremont	11%	5%
Hot Springs	-1%	86%
Lincoln	30%	44%
Park	13%	22%
Sublette	53%	1%
Teton	24%	32%
All GYE Counties	**58%**	**-9%**

Table 2-9 compares recent change in population to recent change in per capita developed land consumption in the 20 GYE counties from 2002 to 2017. Across these 15 years, all GYE counties combined increased in population by 28 percent, while their aggregate per capita land consumption actually decreased by 10 percent. In the same pattern as for the longer 1982 to 2017 time period, one of the two factors (population growth) that drive urban sprawl grew in prominence while the other (per capita land consumption) receded or contracted, at least when aggregated at the overall GYE level. It should be noted, however, that per capita developed land consumption did actually increase in seven of the 20 GYE counties, or about a third of them. However, the counties without increases or with declines had the larger population, which resulted in the overall GYE average reflecting the 10 percent per capita decline.

Table 2-9. Recent Population Growth vs. Recent Growth in Per Capita Developed Land Consumption in GYE Counties, 2002-2017

County	% POPULATION GROWTH, 2002-2017	% GROWTH IN PER CAPITA LAND CONSUMPTION, 2002-2017
Idaho		
Bear Lake	-3%	7%
Bonneville	35%	-11%
Caribou	-3%	3%
Clark	-7%	10%
Fremont	9%	-4%
Madison	38%	-16%
Teton	67%	-7%
Montana		
Beaverhead	5%	-3%
Carbon	10%	-2%
Gallatin	51%	-5%
Madison	20%	-8%
Park	5%	37%
Stillwater	12%	-6%
Sweet Grass	2%	6%
Wyoming		
Fremont	11%	-8%
Hot Springs	-1%	20%
Lincoln	30%	2%
Park	13%	6%

County	% POPULATION GROWTH, 2002-2017	% GROWTH IN PER CAPITA LAND CONSUMPTION, 2002-2017
Sublette	53%	-31%
Teton	24%	-6%
All GYE Counties	**28%**	**-10%**

2.6 MEASURING OVERALL SPRAWL

Using the National Resources Inventory (Developed Land) data, along with county by county Census Bureau population estimates for 1982, 2002, and 2017, we were able to measure the increase in the overall amount of developed land in each of the 20 GYE counties in Idaho, Montana, and Wyoming, and then quantify the fraction or percentage of that sprawl attributable to population growth and that to an increase in per capita developed land use.

Figure 2-13. National Elk Refuge sign in Jackson Hole, Wyoming

3. FINDINGS

This study focuses on the loss or "conversion" of previously undeveloped, or rural, land that includes cropland, pastureland, rangeland, forest, and other wildlife habitat and open space in the Greater Yellowstone Ecosystem of Idaho, Montana, and Wyoming.

At the most basic level, there are three possible reasons for an increase in the area of developed or urbanized land at the expense of the rural land base from which it is derived or "converted": 1) each individual, on average, is consuming more developed land; 2) there are more people consuming the land, that is, a larger population of "urban land consumers"; or 3) a combination of both factors is working together to create sprawl. This study attempts to quantify the relative roles of the two fundamental factors driving urban sprawl: rising per capita land consumption (that is, declining population density) and population growth.

Figure 3-1. Big Sky, Montana sprawls into the surrounding wildland-urban interface (WUI), fragmenting habitat and complicating wildland fire management

3.1 PER CAPITA SPRAWL AND OVERALL SPRAWL

Many respected environmental organizations and urban planners contend that implementing Smart Growth, New Urbanism, and LEED[185] building strategies into our new and existing cities is the best way to rein in sprawl in American cities. However, this is based on the premise that it is only or primarily our land-use choices that cause sprawl in the GYE. As our multiple studies over the past two and a half decades demonstrate decisively, Per Capita Sprawl by itself could not explain Overall Sprawl in the great majority of America's urbanized or developed areas.

The private lands of the 20 GYE counties are no exception. By comparing the aggregate percentage change in per capita land consumption (Per Capita Sprawl) with the aggregate percentage growth of Overall Sprawl (increased in developed land area) in these counties, in **Figure 3-2**, we find that the Per Capita Sprawl percentage is much smaller than the Overall Sprawl percentage: -9 percent versus 44 percent. In fact, in aggregate, Per Capita Sprawl was negative in GYE counties from 1982 to 2017, meaning that, on average, the typical resident used less developed land, not more.

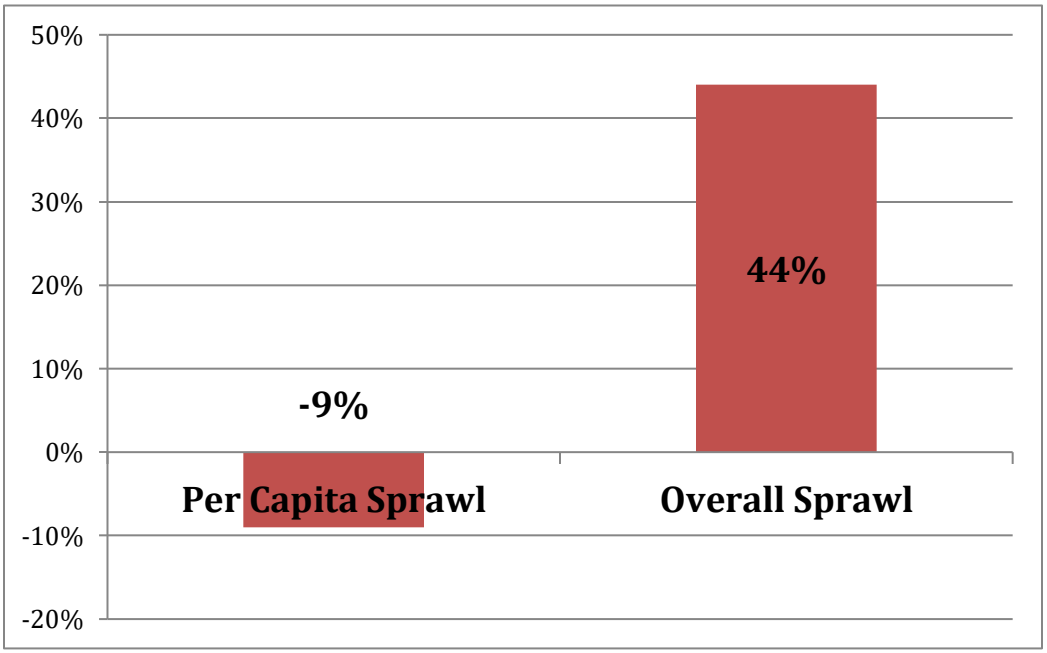

Figure 3-2. Per Capita Sprawl vs. Overall Sprawl in 20 GYE counties, 1982-2017

Note**:** Per Capita Sprawl is % growth in per capita developed land consumption and Overall Sprawl is % growth in developed land area.

[185] LEED stands for Leadership in Energy & Environmental Design. According to the U.S. Green Building Council, LEED "is transforming the way we think about how our buildings and communities are designed, constructed, maintained and operated across the globe. Comprehensive and flexible, LEED is a green building tool that addresses the entire building lifecycle recognizing best-in-class building strategies." http://www.usgbc.org/leed

This is not to denigrate the value of Smart Growth, New Urbanism, and the LEED program, but to recognize their limitations when they omit the population growth factor. Nationwide, these multi-faceted, multi-jurisdictional approaches have indeed slowed the pace at which sprawl is converting the countryside into pavement and buildings. However, given incessant population growth, they are capable only of slowing sprawl, not stopping it.

Table 3-1 compares the percentages of Per Capita Sprawl and Overall Sprawl from 1982 to 2017 in each of the 20 counties in the three-state GYE region. In just three counties out of the 20 counties in the entire GYE did the percentage of Per Capita Sprawl exceed Overall Sprawl – two in Idaho (Bear Lake and Caribou) and one in Wyoming (Hot Springs). Each of these three counties had smaller populations in 2017 than in 1982, so by definition, any increase in developed land (sprawl) they experienced over these 35 years would be entirely related to Per Capital Sprawl (increased per person land consumption or lower population density). However, stepping back and looking at the big picture, or looking at the forest instead of being distracted by the trees, **per capita sprawl** (per capita land consumption) **decreased by nine percent from 1982 to 2017**, while **overall sprawl** (amount of developed land) **increased by 44 percent. Increasing per capita land consumption was clearly not the main driver of urban sprawl in the GYE.**

Table 3-1. Per Capita Sprawl vs. Overall Sprawl in 20 GYE Counties – 1982 to 2017

County	% PER CAPITA SPRAWL, 1982-2017	% OVERALL SPRAWL, 1982-2017
Idaho		
Bear Lake	48%	21%
Bonneville	-11%	52%
Caribou	246%	172%
Clark	3%	9%
Fremont	-3%	14%
Madison	-10%	70%
Teton	5%	279%
Montana		
Beaverhead	17%	28%
Carbon	-13%	11%

County	% PER CAPITA SPRAWL, 1982-2017	% OVERALL SPRAWL, 1982-2017
Gallatin	-9%	117%
Madison	-20%	13%
Park	15%	39%
Stillwater	-24%	23%
Sweet Grass	15%	28%
Wyoming		
Fremont	5%	8%
Hot Springs	86%	46%
Lincoln	44%	98%
Park	22%	53%
Sublette	1%	91%
Teton	32%	193%
All GYE Counties	**-9%**	**44%**

Even the best planning, Smart Growth, New Urbanism, and LEED strategies are able to engineer only so much population density. As long as the population is still growing rapidly, the developed land area within the GYE will continue to grow as well, albeit at a somewhat reduced rate.

3.2 Relative Weight of Sprawl Factors in GYE Counties

To better understand and quantify the respective roles of population growth and per capita developed land consumption in generating Overall Sprawl within the Greater Yellowstone Ecosystem, we can use a more mathematically sophisticated method that is sometimes used to apportion consumption of natural resources between two or more factors. Physicist John Holdren, Ph.D., former Director of the White House Office of Science and Technology Policy and former president of the American Association for the Advancement of Science (AAAS), developed and applied this methodology in a scientific paper evaluating how much of the increase in energy consumption in the United States in the latter part of the 20th

century was due to population growth, and how much to increasing per capita energy consumption.[186] This method can be applied to situations involving virtually any type of natural resource, the consumption of which is increasing over time as a result of an increasing population (number of resource users/consumers), increasing per capita resource use/consumption (everyone is using more, on average), or some combination of both.

This study, as have our other studies over the past two and a half decades, applies this method to sprawl. Rural, undeveloped land – wildlife habitat and farmland, in other words – is thus the resource in question. As in the case of examining energy consumption, the issue here is how much of the increased total consumption of rural land (Overall Sprawl) is related to the increase in per capita developed land consumption (Per Capita Sprawl) and how much is related to the increase in the number of land consumers (Population Growth).

Table 3-2 applies this apportioning methodology to the 20 GYE counties for the entire 1982-2017 study period. Population growth accounted for 67 percent of the 238 square miles of sprawl in the GYE, while growth in per capita developed land consumption (Per Capita Sprawl) was related to 33 percent of the GYE's aggregate sprawl over these 35 years.

Table 3-2. Sources of Sprawl in 20 GYE Counties, 1982-2017

County	Total Sprawl 1982 to 2017 (square miles)	% of Total Sprawl Related to POPULATION GROWTH	% of Total Sprawl Related to GROWTH IN PER CAPITA DEVELOPED LAND CONSUMPTION
Idaho			
Bear Lake	2.5	0%	100%
Bonneville	22.7	100%	0%
Caribou	27.3	0%	100%
Clark	0.6	66%	34%
Fremont	3.1	100%	0%
Madison	9.1	100%	0%

[186] John P. Holdren. 1991. "Population and the Energy Problem." *Population and Environment*, Vol. 12, No. 3, Spring 1991. Holdren served as Director of the White House Office of Science and Technology Policy from 2009-2017; previously he was Professor of Environmental Policy and Director of the Program on Science, Technology, and Public Policy at Harvard's Kennedy School of Government. He co-founded and for 23 years co-led the campus-wide interdisciplinary graduate degree program in energy and resources at the University of California, Berkeley. In 2000 he was awarded the Tyler Prize for Environmental Achievement at the University of Southern California. The Tyler Prize is the premier international award honoring achievements in environmental science, energy, and medical discoveries.

County	Total Sprawl 1982 to 2017 (square miles)	% of Total Sprawl Related to POPULATION GROWTH	% of Total Sprawl Related to GROWTH IN PER CAPITA DEVELOPED LAND CONSUMPTION
Teton	12.2	96%	4%
All ID counties	**77.5**	**95%**	**5%**
Montana			
Beaverhead	8.1	35%	65%
Carbon	1.7	100%	0%
Gallatin	38.1	100%	0%
Madison	3.0	100%	0%
Park	6.1	58%	42%
Stillwater	4.7	100%	0%
Sweet Grass	5.0	44%	56%
All MT counties	**66.7**	**100%**	**0%**
Wyoming			
Fremont	15.0	42%	58%
Hot Springs	3.4	0%	100%
Lincoln	16.7	46%	54%
Park	20.6	54%	46%
Sublette	14.7	99%	1%
Teton	23.0	74%	26%
All WY counties	**93.4**	**86%**	**14%**
Total GYE Sprawl	**237.7**	**100%**	**0%**
Weighted Average*	**237.7**	**67%**	**33%**

*Each county's contribution to aggregate total is weighted by relative amount of its sprawl and % sprawl due to population constrained to between 0-100%.

The value in the next-to-last "Total GYE Sprawl" row in **Table 3-2** represents a high-end estimate (100%) of population's role in driving GYE sprawl. We can obtain a somewhat lower, and we believe, more accurate and realistic, assessment by disaggregating population growth and developed land growth values by county, examining each county in each of the three states individually, and then aggregating their effects on sprawl to derive an overall estimate for the GYE as a whole. This county-by-county weighting approach accounts for the sprawl that occurs in each county and lends a proportionately greater weight to those counties with greater amounts of sprawl. For example, the factors driving sprawl in Gallatin County, Montana, should not be attributed to or lumped in with the distinct factors driving sprawl in geographically distinct Hot Springs County, Wyoming. Bozeman's, Big Sky's, and Gallatin County's population growth and sprawl do not induce sprawl in Hot Springs County.

In this method, the amount of sprawl related to population growth in each county is summed for all 20 counties in the GYE. This sum or aggregate is then divided by the total amount of sprawl in the state. Using this procedure, 67 percent or about two-thirds of the sprawl in the GYE between 1982 and 2017 is shown to be associated with population growth, which the authors believe is a more accurate estimate of population growth's role than 100 percent, the purely mathematical value which exaggerates population's role, and which implies that all sprawl on Greater Yellowstone's private lands is related to population growth; this is not the case.

The results of this more conservative, weighted approach are shown in the last row in **Table 3-2** and in **Figure 3-3**. Here, the percentage of sprawl related to population growth in the 20 GYE counties from 1982 to 2017 is 67%, as opposed to 100% in the previous approach. In both approaches, population growth accounts for well over half of all urban sprawl.

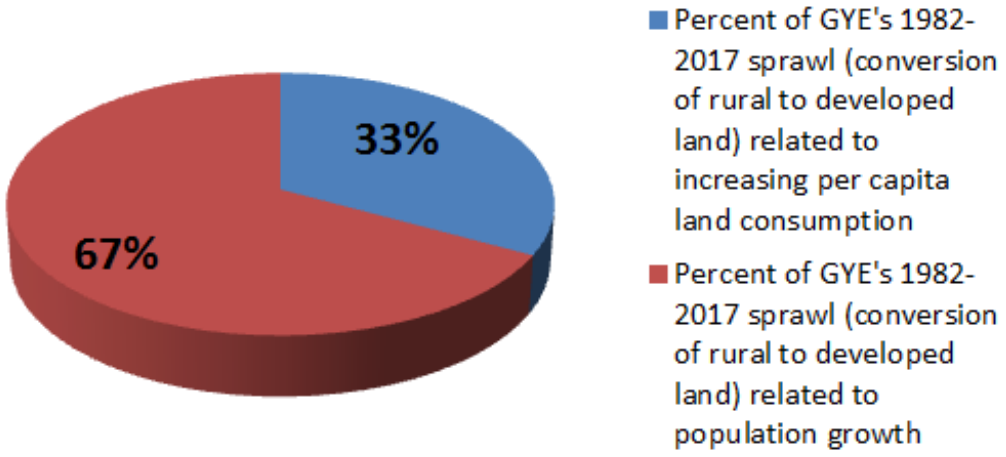

Figure 3-3. Sprawl Factors (Increasing Population and Increasing Per Capita Land Consumption) in GYE Counties, 1982-2017

Figure 3-4 is a bar chart which graphically displays the estimates of how many square miles of GYE sprawl between 1982 and 2017 are related to Population Growth (161 square miles) and how many to Per Capita Sprawl (79 square miles).

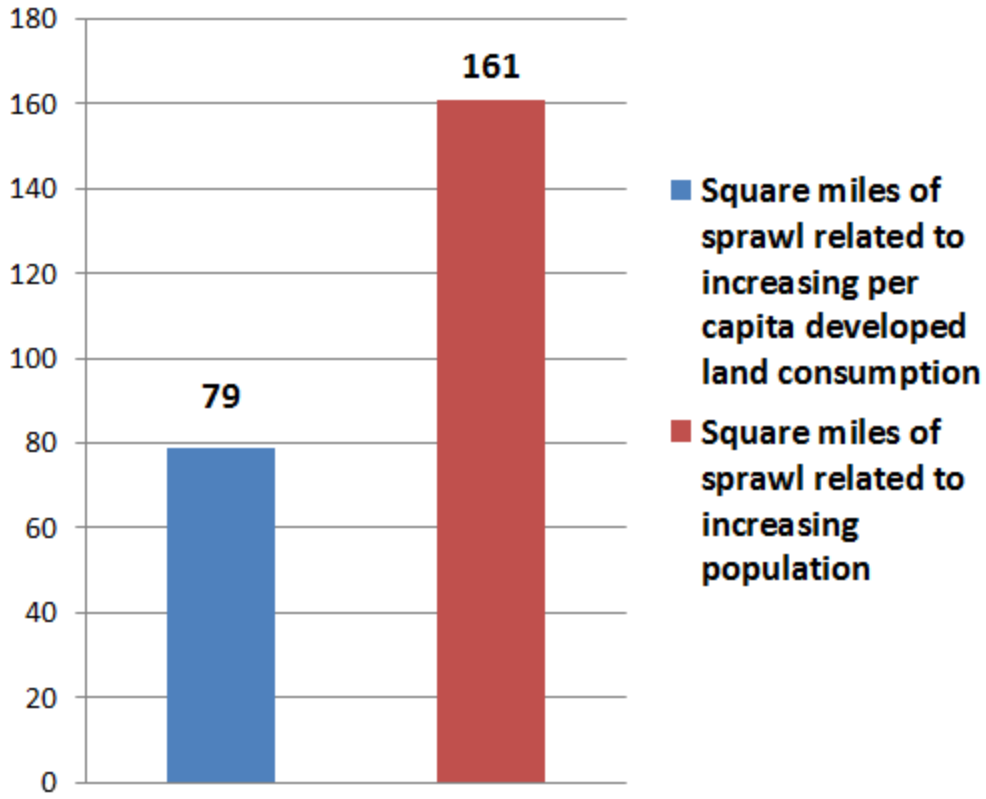

Figure 3-4. Rural Land Lost to Population Growth vs. Per Capita Sprawl in the 20 Greater Yellowstone Ecosystem Counties, 1982-2017

Table 3-3 shows the same variables as **Table 3-2** – total sprawl and the two main drivers of that sprawl – but for the recent time period of 2002 to 2017. During these 15 years, population growth accounted for 85 percent of GYE sprawl, while growth in per capita land consumption was related to 15 percent of sprawl. Thus, the trend over the last few decades is one of population exerting an increasingly greater role in driving sprawl than consumption.

Table 3-3. Sources of Recent Sprawl in 20 GYE Counties, 2002-2017

County	Total Sprawl 2002 to 2017 (square miles)	% of Total Sprawl Related to POPULATION GROWTH	% of Total Sprawl Related to GROWTH IN PER CAPITA DEVELOPED LAND CONSUMPTION
Idaho			
Bear Lake	0.5	0%	100%

County	Total Sprawl 2002 to 2017 (square miles)	% of Total Sprawl Related to POPULATION GROWTH	% of Total Sprawl Related to GROWTH IN PER CAPITA DEVELOPED LAND CONSUMPTION
Bonneville	11.1	100%	0%
Caribou	0.3	0%	100%
Clark	0.2	0%	100%
Fremont	1.3	100%	0%
Madison	3.1	100%	0%
Teton	5.9	100%	0%
All ID counties	**22.3**	**100%**	**0%**
Montana			
Beaverhead	0.6	100%	0%
Carbon	1.3	100%	0%
Gallatin	21.3	100%	0%
Madison	2.2	100%	0%
Park	6.6	12%	88%
Stillwater	1.1	100%	0%
Sweet Grass	1.7	21%	79%
All MT counties	**34.7**	**100%**	**0%**
Wyoming			
Fremont	3.4	100%	0%
Hot Springs	1.7	0%	100%
Lincoln	8.1	95%	5%
Park	10.0	68%	32%
Sublette	1.4	100%	0%
Teton	5.0	100%	0%

County	Total Sprawl 2002 to 2017 (square miles)	% of Total Sprawl Related to POPULATION GROWTH	% of Total Sprawl Related to GROWTH IN PER CAPITA DEVELOPED LAND CONSUMPTION
All WY counties	29.7	100%	0%
Total GYE Sprawl	86.7	100%	0%
Weighted Average*	86.7	85%	15%

*Each county's contribution to aggregate total is weighted by relative amount of its sprawl and % sprawl due to population constrained to between 0-100%.

Figure 3-5 summarizes the findings of **Table 3-3** graphically. Compare it to **Figure 3-3**.

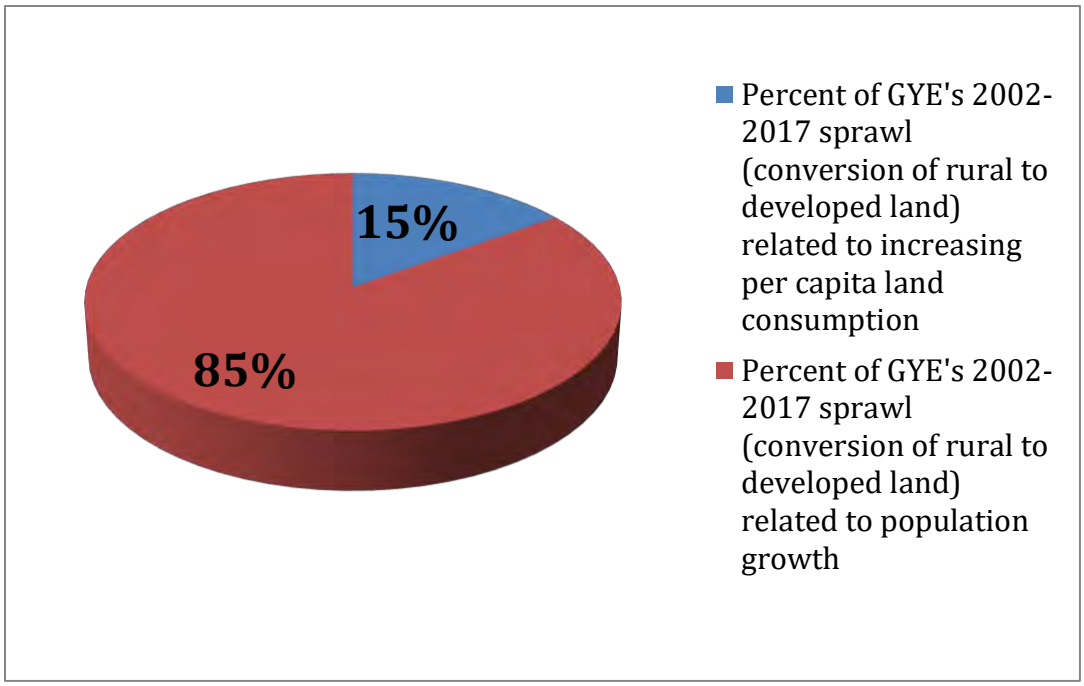

Figure 3-5. Recent Sprawl Factors (Increasing Population and Increasing Per Capita Land Consumption) in GYE Counties, 2002-2017

Figure 3-6 is a bar chart which graphically displays the estimates of how many square miles of recent GYE sprawl between 2002 and 2017 are related to Population Growth (74 square miles) and how many to Per Capita Sprawl (13 square miles). Compare this to **Figure 3-4** (161 versus 79 square miles). The gap between the two fundamental factors or drivers of urban sprawl and loss of open space, wildlife habitat, and farmland on private lands in the Greater Yellowstone Ecosystem has widened. The role of population growth has increased, while that of per capita sprawl has decreased commensurately.

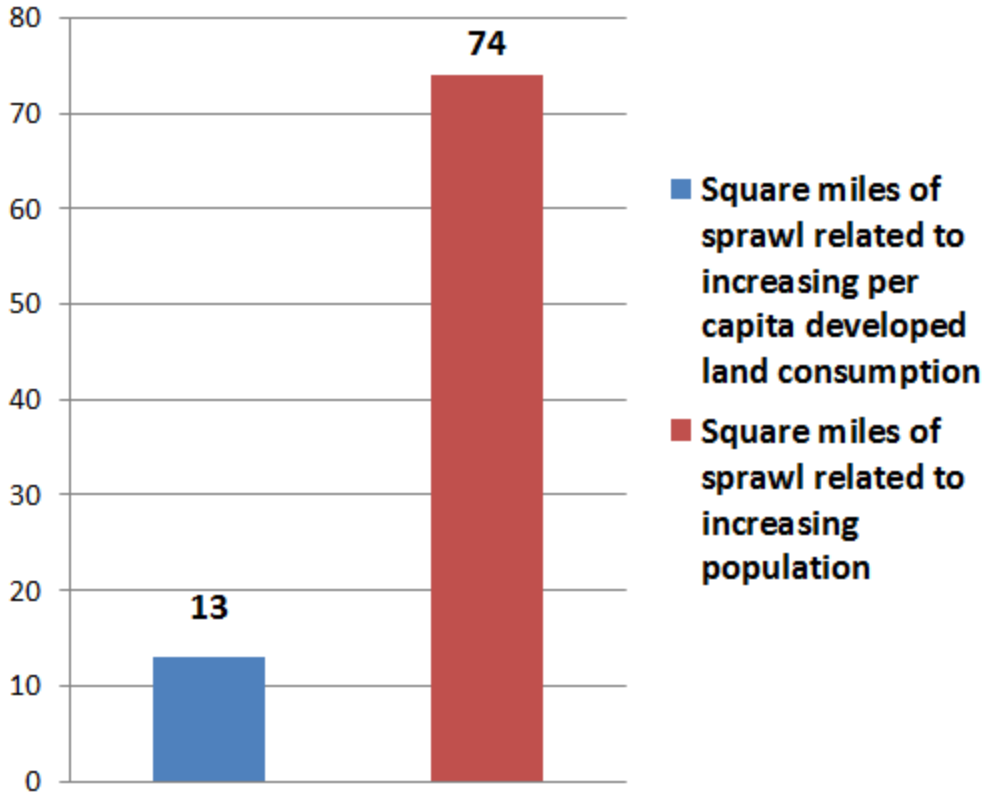

Figure 3-6. Rural Land Lost to Population Growth vs. Per Capita Sprawl in the 20 Greater Yellowstone Ecosystem Counties, 2002-2017

Figure 3-7. Caribou-Targhee National Forest in Idaho portion of GYE
Photo: U.S. Forest Service

3.3 SCATTER PLOTS OF POPULATION GROWTH AND SPRAWL

Another useful way to examine the relationships between the factors in sprawl is by using scatter plot analysis. **Figure 3-8** is a scatter plot for the 20 GYE counties that examines the relationship between each county's population in 2017 on the x-axis (horizontal axis) and the area of developed land (i.e., cumulative total sprawl) on the y-axis (vertical axis). The scatter plot has a "best fit" line that shows the linear relationship between the data points.

The left-to-right, upward-sloping "best fit" line for **Figure 3-8** indicates that there is a positive relationship between population size and overall cumulative area of developed land (Overall Sprawl). Counties with larger populations are also those where more land has been developed cumulatively over time to accommodate the diverse land use needs of that population, which encompass far more than residential land for housing only. Perhaps these results are unsurprising, but if population size and sprawl were unrelated, as some have always maintained, the trend line would be flat or negative (sloping downward toward the right instead of upward). While this scatter plot alone does not prove that population causes sprawl, it strongly suggests and reinforces the hypothesis that the two are correlated.

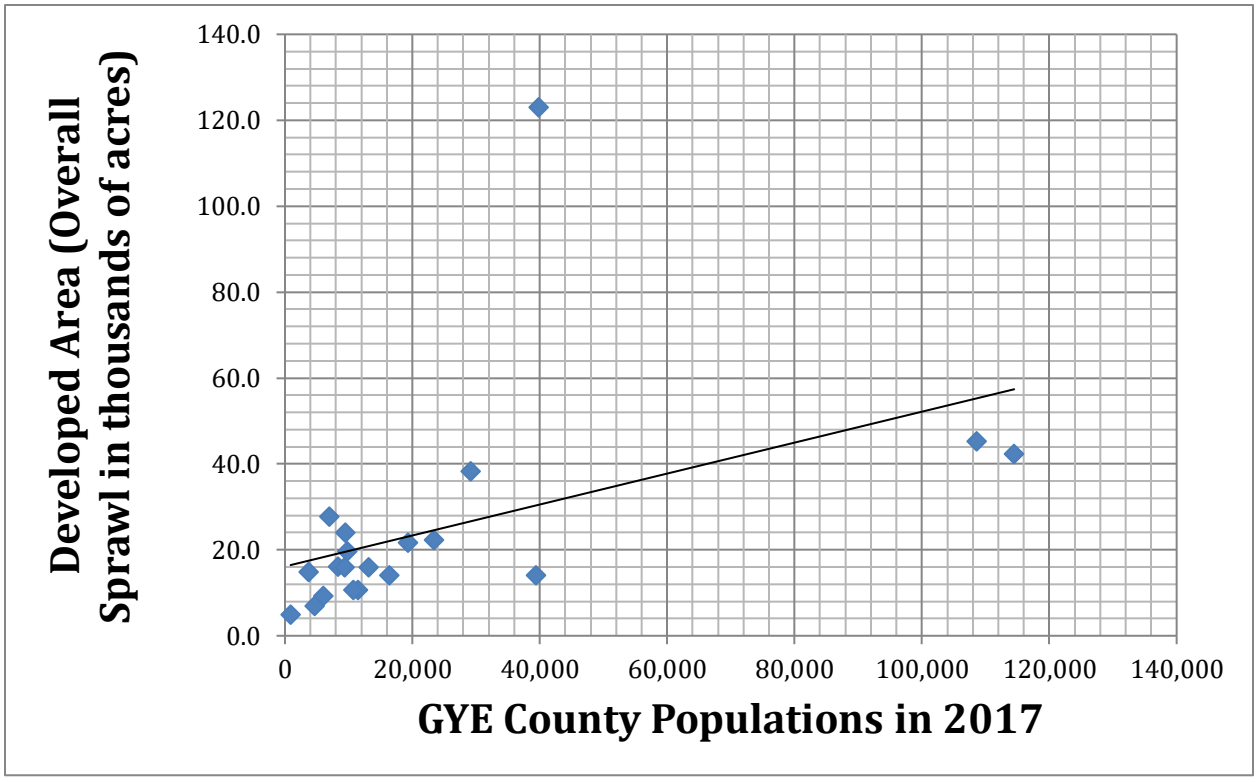

Figure 3-8. Scatter Plot of Population Size vs. Cumulative Developed Land Area (Overall Sprawl) in the 20 GYE Counties, 2017

Sources: Census Bureau 2017 population estimates and National Resources Inventory (2017)

Note that there is one outlier county in **Figure 3-8**, a point (diamond) far outside of the observable cluster of counties in the graph. This happens to be Fremont County, Wyoming, where the Wind River Mountain Range and the Wind River Indian Reservation mentioned in Chapter 1 are located. We do not know why Fremont County is characterized by a far greater amount of developed land (123,000 acres or 192 square miles) for its 2017 population size (39,818) than other GYE counties in the main. However, if we graph a scatter plot of the GYE counties excluding Fremont County, a somewhat different, and perhaps more representative, portrait emerges of the general relationship between county population size and county developed land area (**Figure 3-9).**

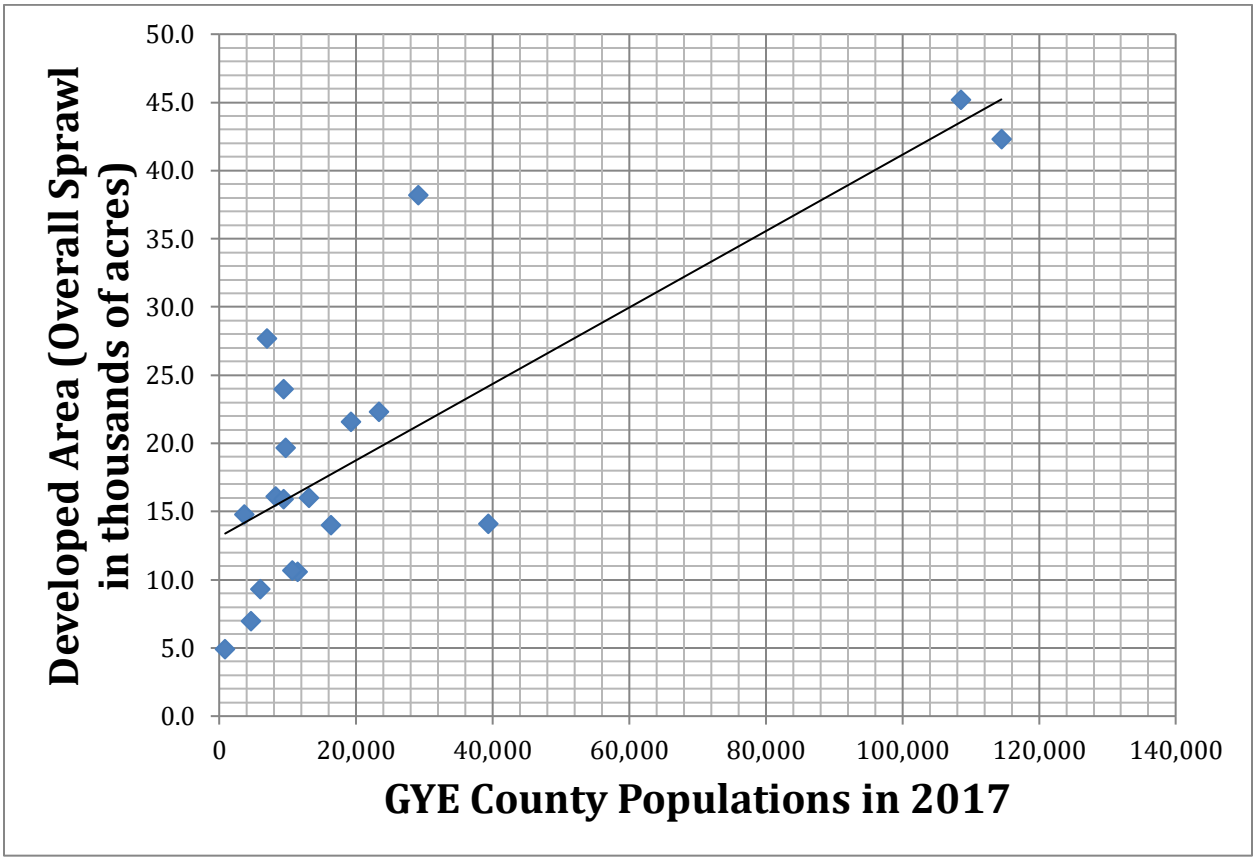

Figure 3-9. Scatter Plot of Population Size vs. Cumulative Developed Land Area (Overall Sprawl) in 19 GYE Counties, 2017 (excluding Fremont County, WY)
Sources: Census Bureau 2017 population estimates and National Resources Inventory (2017)

4. CONCLUSIONS AND POLICY IMPLICATIONS

4.1 CONCLUSIONS

In the private lands of the Greater Yellowstone Ecosystem as a whole, there is a broad correlation between population size and sprawl: generally, the larger a county's population is, the larger the area of land developed to support that population, and the greater the area of wildlife habitat and farmland that is lost and fragmented.

Wildlife habitats and other open space will be permanently converted into developed acreage, that is, into expanding, interconnected assemblages of built structures, pavement, rooftops, and landscaping (e.g., lawns, hedges). These synthetic "habitats" have much less value to native fauna than the GYE's natural habitats or even agricultural habitats (cultivated cropland, pasture used for forage production, and rangeland used for livestock grazing).

In this, the GYE parallels the pattern we have observed and documented throughout the United States as a whole in the more than 15 studies on urban sprawl we have conducted since 2000. In general, the larger a state's population, the larger its developed land area (**Figure 4-1**).

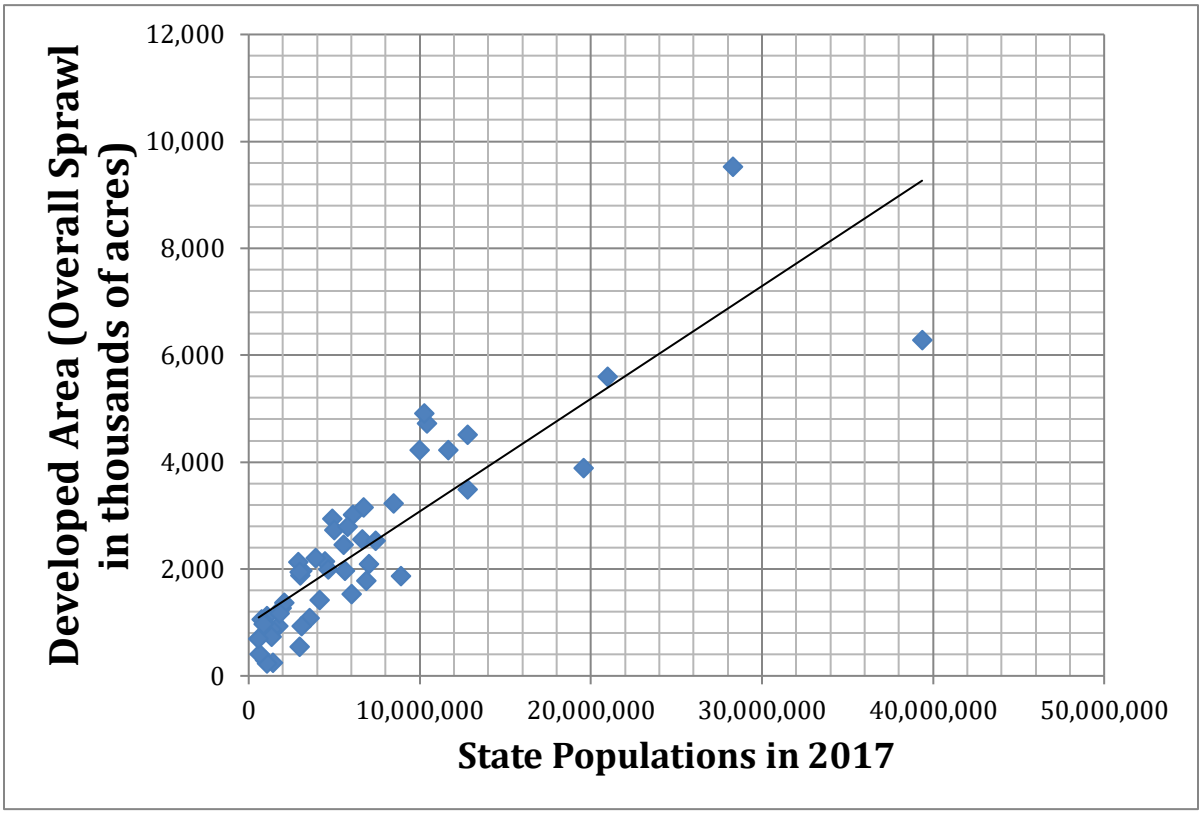

Figure 4-1. Scatter Plot of Population Size vs. Cumulative Sprawl in 49 States, 2017
Sources: Census Bureau state population estimates and National Resources Inventory (2017)

This should not even be controversial, because it coincides with the common sense notion that, *ceteris paribus*, more people means more developed land. But the anti-sprawl and Smart Growth movements that emerged in the 1990s always went out of their way to minimize, ignore, disparage, or deny the role of population growth as a key driver of sprawl. Challenging the myth that population growth was irrelevant was the original impetus behind NumbersUSA's initial sprawl studies a quarter-century ago.

Along with **Figure 4-1**, we also used a common statistical test to measure how closely population size is correlated with the area of developed land (cumulative sprawl) in the 49 states. Correlation coefficients are widely used in the natural and social sciences to measure how strong a relationship is between two variables.[187] In this case, one variable (the independent one) is population size and the other variable (the dependent one) is the "footprint" (area of developed land) that population size imposes on a given state.

In general, correlation coefficients are used to find how strong a relationship is between variables. The various formulas render an "r-value" between -1 and 1, where:

- 1 indicates a strong positive relationship.
- -1 indicates a strong negative relationship.
- A result of zero indicates no relationship at all.

Applying this statistical tool to the data (values) used for the 49 states in **Figure 4-1**, the correlation coefficient r-value is **0.87**, indicating a very strong statistical relationship between population size and developed land area (sprawl). For the GYE, with all 20 counties (**Figure 3-8**) including the outlier Fremont County, the r-value is **0.45**, considered a moderate association; if the Fremont County anomaly is removed (**Figure 3-9**), the r-value rises to **0.79**, a moderate to strong statistical relationship.

Sprawl continues to devour wildlife habitat and farmland on the GYE non-federal land at a rapid rate.

Although the rate of sprawl on non-federal lands in the GYE may have peaked in the 1980s (**Table 4-1**) at approximately 5,800 acres per year (averaging 16+ acres per day), our most recent data through 2017 show that it continues to devour open space at a rate of about 3,230 acres per year (five square miles), or one additional square mile every two months plus. This averages out to about nine acres every day. One caveat is that because our data extend only through 2017, they do not capture the anecdotal evidence many GYE residents adduce for an accelerated rate of sprawling development in the wake of the Covid-19 pandemic and the popular TV series *Yellowstone*; both of these factors are cited as possible contributors to what is believed to be an increase in the rate of arriving newcomers and associated development.

[187] Statistics How To: Correlation Coefficient. Available online at: https://www.statisticshowto.com/probability-and-statistics/correlation-coefficient-formula/#definition.

Table 4-1. Cumulative increase in developed land in the combined 20 GYE counties in 5-Year Intervals, 1982-2017

Year	Area of Developed Land (acres)	Period	Added annual increment of Developed Land during period (acres)	Average daily amount of land consumed by sprawl during period (acres)
1982	345,300			
1987	375,000	1982-1987	5,940	16.3
1992	403,400	1987-1992	5,680	15.6
1997	423,400	1992-1997	4,000	11.0
2002	432,900	1997-2002	3,700	10.1
2007	465,100	2002-2007	4,640	12.7
2012	483,300	2007-2012	3,640	10.0
2017	497,400	2012-2017	2,820	7.7
Average		**1982-2017**	**4,345**	**11.9**

Even at this reduced rate, sprawl would continue to convert an additional 28,200 acres (44 square miles) of the GYE's invaluable rural lands, open space, agricultural land and wildlife habitat into pavement and buildings every decade. By 2060, approximately 102,000 more acres (160 square miles) of the GYE's irreplaceable and invaluable rural lands would be paved or covered with low-density residential development and high-density subdivisions; hotels; industrial and office parks; schools; and commercial strips. This represents a large, permanent, and profound loss to this unique region's wildlife habitat, natural heritage, agricultural land, small town and rural character and economy, quality of life, and environmental sustainability.

By 2025, if the NRCS maintains the same scheduling intervals it has for release of NRI summary reports in recent decades, we should see the publication of new data on developed land up through 2022, and NumbersUSA may update the GYE sprawl study at that time.

Overall, smart growth efforts, relatively higher gasoline prices, fiscal and budgetary constraints (limiting new road-building, for example), the increasing popularity of denser city

living and its cultural amenities, and the recession-inducing mortgage meltdown in 2008 may have all played roles in slowing the GYE's rate of sprawl late in the first two decades of this century from what they were in the last two decades of the 20th century (1980s and 1990s). The extent to which any of these and still other unforeseen factors and events – such as the coronavirus (Covid-19) pandemic of 2020 – may affect the rate of sprawl in the coming decades is unknown and unpredictable. Concerns about high-density residential living in the face of disease pandemics could conceivably increase sprawl pressures by increasing the preference of consumers for lower-density suburban neighborhoods and ex-urban living.

In a comprehensive 2018 study measuring the ecological health of the GYE, Montana State University ecologists Andrew Hansen and Linda Phillips found that 31 percent of the GYE had already been developed by humans.[188] Hansen told *Smithsonian* magazine:

> "Rural homes more or less ring the public land on all sides of the park. It's rather stunning to me to look at a map of all the homes that now surround the park. And changes in these private lands surrounding the park really influences what happens in the park.
>
> "Between all the development surrounding the park, and the increased number of people who are recreating on public lands in and around the park, the pressures have built quite dramatically."[189]

The *Smithsonian* article states that "the most notable change in the [Greater Yellowstone] ecosystem is the number of humans present in the region and the ways they impact it." One of the most significant ways is by human development interfering with ecosystem connectivity and wildlife migration corridors used by "many elk, bison, pronghorn and other ungulates [which] summer in the park but in winter head to lower elevations, and increasingly developed private lands, where they aren't always welcome and are frequently hunted." Wide-ranging carnivores such as wolves, wolverines, and grizzly bears, which have large home ranges (territories), "are more frequently being killed on roads or getting into trouble with humans outside of the boundaries." Growing human pressures on the ecosystem also contribute to the proliferation of invasive terrestrial and aquatic species which harm native flora and fauna.[190]

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[188] Andrew J. Hansen and Linda Phillips. 2018. Trends in vital signs for Greater Yellowstone: application of a Wildland Health Index. *Ecosphere: An ESA Open Access Journal*. 16 August. Accessed online on 7-23-2024 at: https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecs2.2380. Note that criteria and definitions for "development" can differ; the definition used here does not correspond to our own.

[189] Brian Handwerk. 2022. Five Big Changes Scientists Have Documented During Yellowstone National Park's 150-Year History: Scientists have monitored the region closely for generations, and these are some of the most dramatic shifts they've seen. *Smithsonian*. April 7. Accessed online on 7-23-2024 at: https://www.smithsonianmag.com/science-nature/five-big-changes-scientists-have-documented-during-yellowstones-150-year-history-180979827/.

[190] Ibid.

Figure 4-2. Sign along rural road in the Gallatin Valley warns motorists of crossing elk
Photo credit: Leon Kolankiewicz

The population growth rate in the GYE is much higher than in the country as a whole and is influenced by a number of factors – some predictable, others not so much.

It is interesting to compare recent population growth rates in the GYE and the United States as a whole (**Table 4-2**).

Table 4-2. Recent Population Growth Rates in the Greater Yellowstone Ecosystem (GYE) and the United States (USA)

Time Period	# years in time period	CAGR*	Area
2020-2023	3	1.60%	GYE
2010-2020	10	1.50%	GYE
2020-2023	3	0.54%	USA
2010-2020	10	0.63%	USA

* compound annual growth rate (CAGR)

Table 4-2 shows that the compound annual growth rate (or CAGR, also called the exponential annual growth rate) for the GYE increased slightly from 1.50% in the 2010-2020 time period to 1.60% in the most recent 2020-2023 time period. This contrasts with the United States as a whole, in which the CAGR decreased slightly from 0.63% in the 2010-

2020 time period to 0.54% in the most recent 2020-2023 time period. In other words, while population growth in the United States was decelerating, at the same time in the GYE, it was accelerating. It is also worth emphasizing that the annual population growth rate in the GYE from 2020 to 2023 (1.60%) is about three times that of the United States overall (0.54%). The perception on the part of many GYE residents that the region is growing relatively fast is borne out by these Census Bureau demographic data.

An article in *The New York Times* stated in April 2020:

> "The [Covid-19] pandemic has been particularly devastating to America's biggest cities, as the virus has found fertile ground in the density that is otherwise prized. And it comes as the country's major urban centers were already losing their appeal for many Americans, as skyrocketing rents and changes in the labor market have pushed the country's youngest adults to suburbs and smaller cities often far from the coasts."[191]

The same article quoted Brookings Institution demographer William Frey, who noted that even before the coronavirus pandemic, "millennials and older members of Generation Z were already increasingly choosing smaller metro areas like Tucson, Ariz.; Raleigh, N.C.; and Columbus, Ohio…. Also growing were exurbs and newer suburbs outside large cities. 'There was a dispersion from larger metros to smaller metros, from urban cores to suburbs and exurbs.'"

California is one large source, nearly 40 million residents in size, that has sent many thousands of domestic migrants to the GYE in recent years; and if the cost of living continues to skyrocket while the quality of life in that overpopulated state continues to deteriorate, this hemorrhaging and exodus are likely to continue or even accelerate, with the vaunted Greater Yellowstone Ecosystem one such "greener pasture" yearned for by many. As noted in an April 2024 article in *the Los Angeles Times* by political columnist and veteran California observer George Skelton:

> California just got too big for its carrying capacity — at least in the sprawling, ranch-house lifestyle that so many people covet and symbolizes the state's easy-living persona.
>
> "Grow and grow and grow and eventually there's not enough room," says Hans Johnson, a demographer at the nonpartisan Public Policy Institute of California.
>
> "The easy places for growth have been used up. Growth today means infill development [in cities]. That's expensive and controversial. Or you live further away from your job."

[191] Sabrina Tavernise and Sarah Mervosh. 2020. America's Biggest Cities Were Already Losing Their Allure. What Happens Next? *New York Times*. April 19. Accessed online on 4/22/2020 at: https://www.nytimes.com/2020/04/19/us/coronavirus-moving-city-future.html. The article also quoted Harvard University economics professor Ed Glaeser, author of *Triumph of the City*, who said: "It feels like it's back to smallpox, back to cholera. Cities were killing fields for centuries because of contagious disease."

> Or leave the state and find cheaper housing almost anywhere.
>
> Out-of-state migration is the main cause of California's continuing population loss.[192]

Another potential, looming factor of great uncertainty but great risk is climate change. As the century proceeds, increasing water scarcity and even hotter temperatures are predicted in the already hot and arid American Southwest.[193] Increasingly inhospitable, uninhabitable, and unviable living conditions for the tens of millions of Americans who live there may accelerate migration northward and concomitant, intensified growth in the northern, relatively cooler and wetter parts of the country, such as the Northern Rockies where the GYE is situated.

In his 2024 book *On the Move: The Overheating Earth and the Uprooting of America*, ProPublica and *New York Times* environmental journalist Abrahm Lustgarten warns that, "Humanity is on the precipice of a great climate migration, and Americans will not be spared," according to the book description at Amazon.com:

> *On the Move* is the definitive account of what this massive population shift might look like. As [Lustgarten] shows, the United States will be rendered unrecognizable by four unstoppable forces: wildfires in the West; frequent flooding in coastal regions; extreme heat and humidity in the South; and droughts that will make farming all but impossible across much of the nation.[194]

The Amazon.com description for *On the Move* continues: "Employing the most current climate data and predictive models, he shows how America's population will be squeezed northward into a shrinking triangle of land stretching from Tennessee to Maine to the Great Lakes." Note that the Northern Rockies are excluded – perhaps they are included in a West that may be overwhelmed with frequent and devastating wildfires – but there is a good deal of inherent uncertainty in such predictions.

If current population trends are allowed to continue, the GYE will experience vast amounts of sprawl over the coming decades.

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[192] George Skelton. 2024. Why Californians are fleeing this once-Golden State. *Los Angeles Times*. April 8. Accessed online on 7-23-2024 at: https://www.latimes.com/california/story/2024-04-08/why-californians-are-fleeing-this-once-golden-state.

[193] Gonzalez, P., G.M. Garfin, D.D. Breshears, K.M. Brooks, H.E. Brown, E.H. Elias, A. Gunasekara, N. Huntly, J.K. Maldonado, N.J. Mantua, H.G. Margolis, S. McAfee, B.R. Middleton, and B.H. Udall, 2018: *Southwest*. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 1101–1184. doi: 10.7930/NCA4.2018.CH25. Accessed online on 7-23-2024 at: https://nca2018.globalchange.gov/chapter/southwest.

[194] Abrahm Lustgarten. 2024. *On the Move: The Overheating Earth and the Uprooting of America*. Farrar, Straus and Giroux. https://www.amazon.com/Move-Overheating-Earth-Uprooting-America/dp/0374171734/ref=cm_cr_arp_d_product_top?ie=UTF8.

Not all of the states in the GYE have official state population projections beyond 2030, but other reputable, professional demographers have made projections out to the year 2060 for the 20 counties in the GYE. One such set of projections is shown in **Table 4-3**.

Table 4-3. GYE Population Projections by County, 2020-2060

County	Population 2020	Projected Population 2060	Population Change, 2020-2060	Percentage Increase or Decrease
Idaho				
Bear Lake	6,372	6,092	-280	-4.4%
Bonneville	123,964	189,702	65,738	53.0%
Caribou	7,027	7,508	481	6.8%
Clark	790	1,067	277	35.1%
Fremont	13,388	13,931	543	4.1%
Madison	52,913	81,283	28,370	53.6%
Teton	11,630	22,327	10,697	92.0%
All ID counties	**216,084**	**321,910**	**105,826**	**49.0%**
Montana				
Beaverhead	9,371	10,678	1,307	13.9%
Carbon	10,473	11,967	1,494	14.3%
Gallatin	118,960	239,470	120,510	101.3%
Madison	8,623	10,050	1,427	16.5%
Park	17,191	20,914	3,723	21.7%
Stillwater	8,963	9,885	922	10.3%

County	Population 2020	Projected Population 2060	Population Change, 2020-2060	Percentage Increase or Decrease
Sweet Grass	3,678	3,249	-429	-11.7%
All MT counties	**177,259**	**306,213**	**128,954**	**72.7%**
Wyoming				
Fremont	39,234	28,415	-10,819	-27.6%
Hot Springs	4,621	2,736	-1,885	-40.8%
Lincoln	19,581	30,468	10,887	55.6%
Park	29,624	32,747	3,123	10.5%
Sublette	8,728	5,603	-3,125	-35.8%
Teton	23,331	35,379	12,048	51.6%
All WY counties	**125,119**	**135,348**	**10,229**	**8.2%**
Entire GYE	**518,462**	**763,471**	**245,009**	**47.3%**

Data sources: U.S. Census Bureau population count 2020; 2060 projection from: http://proximityone.com/demographics2060.htm; U.S. County Population Trends: 2010 - 2060 Interactive Table;

Table 4-3 projects that the 20-county GYE's population will grow from 518,462 in 2020 to 763,471, an increase of 245,009 or 47 percent. How much additional acreage of developed land would this population increase of nearly a quarter million residents in the GYE result in? The best we can do is predict a range, based on alternative assumptions. Starting with the most pessimistic assumption, in 2017, the most recent year for which we have NRI data, there were 1.03 acres of developed land per GYE resident: 497,400 developed acres for 484,883 residents. (This represented a decrease from 1.14 acre/person in 2002.) If future population growth entailed rural land being developed at the 2017 rate, that in turn would entail an additional 252,360 acres of now-rural, private land in the 20 GYE counties being developed by 2060. This would, of course, impose adverse effects on the region's wildlife and migratory ungulate populations, by reducing habitat and impeding access to it.

However, this is a *projection*, not a *prediction*, and it is not a *fait accompli*. Assuming a more optimistic (higher) population density, we could use a per capita land use consumption value of 0.4 acre. This value is midway between that of Bonneville County, Idaho (0.37 acre per capita) and Gallatin County, Montana (0.42 acre per capita) in 2017. These are the two most populous and highest population density counties in the GYE, and where much of the projected future growth would occur. Under this assumption (0.4 acre per capita), 98,000 acres of rural land would be developed by 2050 to accommodate the projected population growth.

Therefore, with reasonable confidence and accuracy, we can predict that future sprawl in the GYE region might range from about 98,000 to 252,000 acres, or 153 to 394 square miles. In 2017, there were 777 square miles of land developed cumulatively in the 20 GYE counties, and it took all of history to reach this amount. Over the coming 35 years alone, if projected population growth occurs, the amount of rural land developed to accommodate that population growth would increase the cumulative total of developed land by some 20 to 51 percent. This is substantial, and it would represent a substantially adverse effect on the region's large mammal populations.

Projections are not predictions and they are not set in stone.

Professional demographers hasten to emphasize that they do not have proverbial crystal balls when it comes to foreseeing the future. The population projections they make, based on reasonable, credible assumptions as to future rates of a county's, state's or the country's mortality, fertility, in-migration, and out-migration, are decidedly not predictions. They are merely the possible outcomes of extended series of current demographic factors and trends that must be heavily caveated.

Unforeseen or unpredictable future events ("black swans" in the coinage of analyst and aphorist Nassim Nicholas Taleb) and policy reforms can lead to dramatic, even startling, changes in demographic destinies and trajectories. A prime example of this is another Western state – immense California – whose demographic fortunes and surprises have played such an outsized role in the recent demography of other Western states, including Idaho, Montana, and Wyoming.

The California Department of Finance provides official demographic projections for the state. Throughout the 20th century, and up to and including its previous projections of 2013, the Department of Finance projected essentially endless population growth for California, or at least growth for as far as the demographers' eyes could see (**Figure 4-3**).

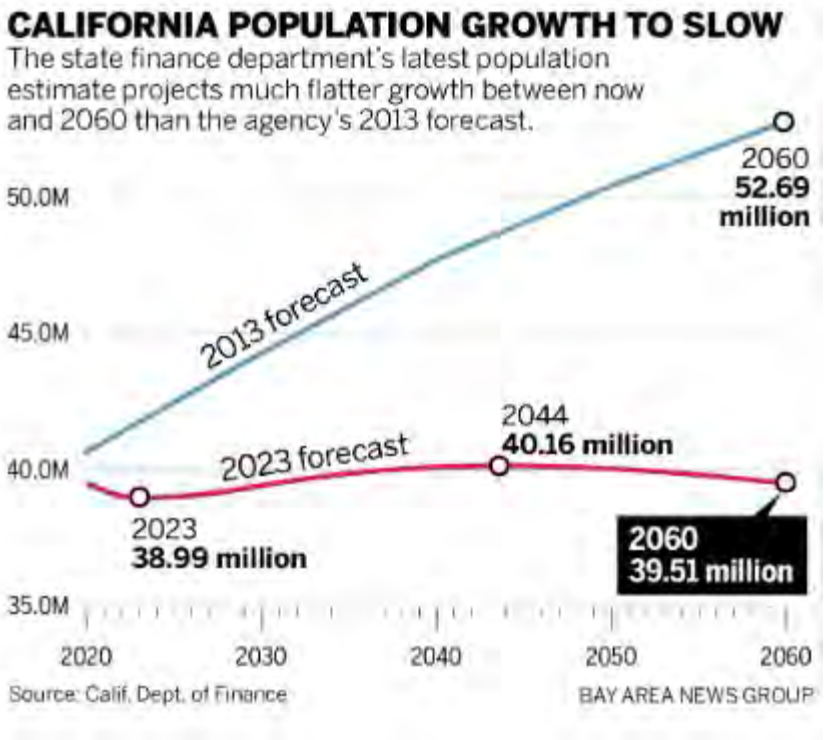


Figure 4-3. Changes in California's Official Demographic Projections
Sources: California Dept. of Finance and Bay Area News Group

In the previous official state demographic projections made in 2013 ("2013 forecast" in the figure), based on the best data then available to state demographers, California's population was projected to continue growing rapidly until 2060, at which point it would have topped 52 million and still be growing very rapidly (as indicated by the steep slope of the line in 2060.) However, in its more recent 2023 projections, released last year, the Department of Finance now forecasts a decidedly distinct future for California from the one forecast just a decade ago.

Instead of a population approaching 53 million in 2060, and still increasing, California is now forecast to have a 2060 population under 40 million, or 39 million plus, essentially what it is today. For the time being at least, California's population appears to have more or less stabilized (it has declined for the past four years), although not because the large number of people continuing to move into the state from foreign countries has ebbed. Rather, it has stabilized because the exodus of Californians – fed up with and fleeing everything from soaring home prices to soul-crushing traffic, out-of-control crime, and draconian lockdown policies during the Covid-19 pandemic – out of the state now approximately offsets the foreign influx into the state plus births.

The lesson from these divergent California population projections is relevant to the case of future population growth in the GYE as well. The projections in **Table 4-3** are not a given.

Nor are perpetual losses of the Greater Yellowstone Ecosystem's wildlife habitat to never-ending development and sprawl.

4.2 POLICY IMPLICATIONS

In order for policy-makers to reduce the negative impacts of sprawl and over-development in the GYE, they must adopt a two-pronged approach. Building on the findings of our original sprawl studies in 2000 and 2001, and using the same analysis of U.S. Census Bureau and U.S. National Resource Conservation Service data, this study provides further evidence of the necessity for such a two-pronged approach in order to effectively combat loss of wildlife habitat and farmland to sprawl in the Greater Yellowstone Ecosystem. Furthermore, this study found that the role of population growth in contributing to Overall Sprawl has remained high in the GYE over the past four decades. These findings further reinforce the need for measures that both reduce wasteful over-consumption of our land and natural resources as well as others that address the large population growth that persists in our country as a whole and in the GYE in particular.

While the findings of this study directly challenge the assumptions of many Smart Growth and New Urbanism advocates that population growth plays only an insignificant or peripheral role in Overall Sprawl, they do not discount the necessity for smarter urban and regional planning that reduces per capita land consumption. The results of this study suggest that in the GYE only about a third of long-term sprawl (1982-2017), and about 15 percent of recent sprawl (2002-2017) and open space loss is related to a complex matrix of zoning laws (or lack of them), infrastructure subsidies, and socioeconomic forces. Planning efforts to make GYE towns and communities more space-efficient by reducing per capita land consumption (increasing population density) are certainly needed, but they largely ignore the main factor behind the sprawl and development that are steadily eating away at privately-owned rural lands – and the wildlife habitat, migration corridors, and farmland they contain – in the Greater Yellowstone Ecosystem.

Following the logic of this study's findings it isn't hard to conclude that even the most aggressive and well-intentioned policies promoting smarter growth, better urban/regional planning, and higher residential densities cannot escape the immense population pressures facing many GYE communities. In recent years, as noted in the first section of this study, the GYE's aggregate population has grown two to three times faster (measured by percentage increase) than the United States as a whole.

4.2.1 Local Approaches to Manage GYE Sprawl and its Adverse Effects

Smart Growth Approach to Controlling Sprawl

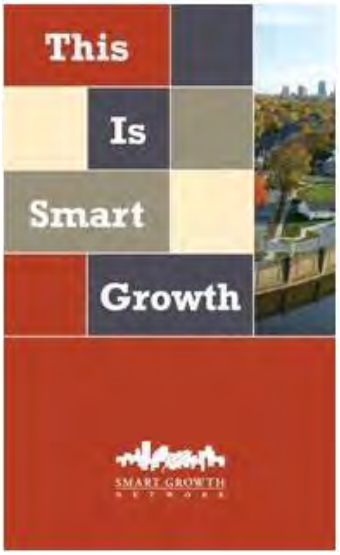
Local policy makers truly trying to curb sprawl in the GYE towns and cities of Idaho, Montana, and Wyoming have a number of policy actions and instruments at their disposal.

While most local officials typically see population growth as an indicator of the vibrancy and vitality of their respective communities, there is little evidence to suggest that unfettered, long-term population growth is any of those things. Well-known Eugene, Oregon-based sprawl critic and urban planner Eben Fodor, author of *Better Not Bigger*, challenged this very notion in his 2010 study "Relationship between Growth and Prosperity in 100 Largest U.S. Metropolitan Areas." [195]

Fodor's study found that rapidly expanding metropolitan areas did not hold up well in terms of standard economic indicators such as unemployment rates, per capita income, and poverty rates in comparison with slower growing metropolitan areas. Yet, despite this, local officials and city planners continue to offer subsidies and tax breaks to attract new residents, investment and development. Many times these subsidies are born unfairly by existing residents, who see their property taxes rise and are stuck paying the bill for sprawling highways, new schools, water and wastewater treatment, and energy grids ever farther from the urban core.

Many cities have overly complicated or restrictive zoning laws that drive up home prices. New immigrants and low income families are being priced out and into the more affordable suburbs and Sunbelt cities. Sprawl in the Sunbelt is of particular concern because its growth puts added strain on already scarce water resources. In order for cities to properly address sprawl, taxpayer subsidies need to be removed and the true costs of development need to be borne by those developing the land. Also, as suggested by Harvard economist Edward Glaeser, author of *Triumph of the City*, the true social costs of activities such as driving should be paid for. More sensible planning policies and zoning ordinances can help curb sprawl and reduce the size of population booms in areas not suited to handle large populations.

The U.S. Environmental Protection Agency (EPA) has a website devoted to Smart Growth at: https://www.epa.gov/smartgrowth. It contains a number of practical resources for planners, activists, developers, and local officials to help promote smart growth, which EPA defines as: "a range of development and conservation strategies that help protect our health and natural environment and make our communities more attractive, economically stronger, and more socially diverse."



The EPA Smart Growth website lists the 10 principles of smart growth developed in 1996 by the Smart Growth Network, an alliance of environmental, affordable housing, real estate and

[195] Eben Fodor. 2012. Relationship Between Growth and Prosperity in the 100 Largest U.S. Metropolitan Areas. *Economic Development Quarterly*. Available at: http://edq.sagepub.com/content/26/3/220.

development, historic preservation, public health, government, and other groups. The ten principles of Smart Growth are:

- Mix land uses
- Take advantage of compact building design
- Create a range of housing opportunities and choices
- Create walkable neighborhoods
- Foster distinctive, attractive communities with a strong sense of place
- Preserve open space, farmland, natural beauty, and critical environmental areas
- Strengthen and direct development toward existing communities
- Provide a variety of transportation choices
- Make development decisions predictable, fair, and cost effective
- Encourage community and stakeholder collaboration in development decisions

In recent years, a growing pro-development citizens' movement in urban centers has emerged and been making waves. This so-called YIMBY movement (for "Yes In My Backyard", in explicit contrast to the NIMBY or "Not In My Backyard" movement) began in San Francisco in the early 2010s, fueled by millennials fed up with astronomical housing prices that effectively priced them out of living in the city. According to *The Guardian*, YIMBY advocates see themselves as progressive housing activists welcoming higher density and rents and mortgages affordable to the middle class, while their detractors denounce them as dupes for luxury developers, contributing to the gentrification of urban centers.[196] In San Francisco, NIMBYs have clashed with Hispanic organizations over housing developments proposed for the low-income, traditionally Hispanic Mission District.

In the authors' view, in general, Smart Growth principles and strategies should be pursued for the sake of environmental sustainability and neighborhood livability in any case, regardless of the amount of population growth that is occurring. From the findings of this study however, as well as recent experience around the country, it is quite evident that Smart Growth alone will not stop urban sprawl from devouring the countryside. Physicist and famed population activist Dr. Albert Bartlett wrote that: "smart growth will destroy the environment, but it will do it in a sensitive way." The authors would phrase this idea

[196] Erin McCormick. 2017. Rise of the yimbys: the angry millennials with a radical housing solution. *The Guardian*. October 2. Retrieved online April 26, 2020 at: https://www.theguardian.com/cities/2017/oct/02/rise-of-the-yimbys-angry-millennials-radical-housing-solution.

somewhat differently: smart growth is necessary but not sufficient to save natural habitats an farmland from incessant sprawl.

In early 2020, the Covid pandemic threw a curve ball into all of these long-term trends and emerging considerations, and proponents of higher urban densities were put on the defensive. As the headline of an article in the *Los Angeles Times* expressed it: "Building dense cities was California's cure for the housing crisis. Then came coronavirus."[197]

The American Farmland Trust (AFT) promotes what they call the "Better Built Cities" approach. Under this "policymakers and land-use planners promote compact development and reduce sprawl, saving irreplaceable farmland and ranchland from conversion."[198] AFT claims that by implementing this, by embracing smart growth principles and improving land-use planning, Americans could "slash conversion" of farmland to developed land by up to 55 percent and save up to 13.5 million acres of farmland nationwide by 2040. AFT also advocates for permanently protecting more agricultural land via Purchase of Agricultural Conservation Easement (PACE) programs and providing incentives (such as property tax relief) for keeping land in agricultural production.[199]

In our late July 2024 opinion survey of 829 Idaho, Montana, and Wyoming likely voters, a joint effort of Rasmussen Reports and NumbersUSA (see Appendix E), we asked what they thought of attempts to curb sprawl on private lands of the GYE by changing zoning and land use management to raise population densities in the region's residential and developed areas. A slim majority (55%) of ID-MT-WY likely voters strongly or somewhat favored increasing density as a way of accommodating further population growth while slowing down (if not stopping) sprawl. A not insubstantial minority (36%, or more than one third) "strongly" or "somewhat" opposed such measures. There is not unanimity but does appear to be majority political support for such measures.

> One way to accommodate continued population growth in Greater Yellowstone without losing as much natural habitat and farmland to development would be to increase population density by changing zoning and other regulations so more residents live in apartments.
>
> 24% Strongly favor
> 31% Somewhat favor
> 20% Somewhat oppose

[197] Liam Dillon. 2020. Building dense cities was California's cure for the housing crisis. Then came coronavirus. *Los Angeles Times*. April 26. Accessed online April 26, 2020 at: https://www.latimes.com/homeless-housing/story/2020-04-26/coronavirus-density-cities-urbanization-housing-climate-change.

[198] American Farmland Trust. Explore the Future of Farmland. Available online at: https://development2040.farmland.org/#:~:text=Better%20Built%20Cities%3A%20Policymakers%20and,other%20farms%20reinforces%20compact%20development.

[199] Hunter, M., A. Sorensen, T. Nogeire-McRae, S. Beck, S. Shutts, R. Murphy. 2022. *Farms Under Threat 2040: Choosing an Abundant Future*. Washington, D.C.: American Farmland Trust.

16% Strongly oppose
10% Not sure

Among residents and neighbors of the GYE (those who live within a 3-hour drive of Yellowstone or Grand Tetons National Parks), support for local planning measures to reduce the rate of sprawl by increasing population density in developed areas is somewhat higher than among IT-MT-WY residents as a whole, at 59 percent:

One way to accommodate continued population growth in Greater Yellowstone without losing as much natural habitat and farmland to development would be to increase population density by changing zoning and other regulations so more residents live in apartments.
30% Strongly favor
29% Somewhat favor
20% Somewhat oppose
15% Strongly oppose
7% Not sure

When the question is framed somewhat differently, there is even stronger support among ID-MT-WY respondents – almost two-thirds – for local planning measures to reign in sprawl:

Zoning, urban growth boundaries, and limiting the number of new hook-ups to sewage treatment systems are examples of planning or "smart growth" tools for accommodating population growth while attempting to reduce new development and sprawl from spreading further into the surrounding countryside. Do you favor using such planning tools as a means of limiting sprawl?
64% Yes
15% No
21% Not sure

Once again, among residents and neighbors of the GYE (those who live within a 3-hour drive of Yellowstone or Grand Tetons National Parks), there is even stronger support – slightly more than two-thirds (67%) – for such measures:

Zoning, urban growth boundaries, and limiting the number of new hook-ups to sewage treatment systems are examples of planning or "smart growth" tools for accommodating population growth while attempting to reduce new development and sprawl from spreading further into the surrounding countryside. Do you favor using such planning tools as a means of limiting sprawl?
67% Yes
15% No
17% Not sure

There is also strong opposition among IT-MT-WY likely voters to being forced to pay higher property taxes to accommodate new residents and residential development in their own communities, with nearly seven out of ten (69%) respondents expressing their opposition:

Do you favor paying higher property taxes to accommodate new residents and residential development into your community?
20% Yes
69% No
11% Not sure

Interestingly, the percentage opposed to paying higher taxes to accommodate new residents drops slightly (to 64%) among residents and neighbors of the GYE, although it is still a strong majority:

Do you favor paying higher property taxes to accommodate new residents and residential development into your community?
27% Yes
64% No
9% Not sure

In summary, the results of this late July 2024 public opinion survey indicate that slight but not overwhelming majorities of ID-MT-WY likely voters, and GYE residents and neighbors in particular, support local and regional (e.g., municipal, county, regional, statewide, etc.) efforts to reduce the rate of sprawl in the GYE by implementing planning measures that have the net effect of increasing population densities in already developed and newly developing areas or those slated for future development. This tends to accommodate regional population growth while slowing (though not halting) sprawl into the surrounding countryside. It might be characterized as the "having our cake and eating it too" approach to external growth pressures, or less cynically, as growth management or smart growth. Based on more than two decades of sprawl studies around the country, we believe that such measures have indeed enjoyed partial success in slowing (if not stopping) urban sprawl and loss of open space, farmland, and wildlife habitat. The question is whether this partial success itself is sustainable.

Measures Specific to the Greater Yellowstone Ecosystem

In his important 2022 book *Ripple Effects: How to Save Yellowstone and America's Most Iconic Wildlife Ecosystem*,[200] veteran Yellowstone conservationist, journalist, and author Todd Wilkinson (who also wrote the foreword to this study), who also founded the new conservation journalism site *Yellowstonian* (yellowstonian.org), lists a number of "Big Ideas That Would Save Greater Yellowstone," and we list and describe several of those here that are pertinent to the campaign to curb land-devouring sprawl in the GYE:

- Land Use Zoning: Wilkinson notes that: "fragmented planning results in fragmented degraded landscapes unfit for wildlife and agriculture. Part of the approach to dealing

[200] Todd Wilkinson. 2022. *Ripple Effects: How to Save Yellowstone and America's Most Iconic Wildlife Ecosystem*. https://www.amazon.com/Ripple-Effects-Yellowstone-Americas-Ecosystem/dp/B0BPL798QD.

with growth and development issues must necessarily involve land-use zoning. Zoning needs to stop being treated as a taboo topic. Together, wildlife migrations and zoning can work in tandem in identifying and protecting vital wildlife habitat and identifying the best places where human development on private lands should occur."

- New Funding Sources for Land Protection: Duck Stamps and the Land and Water Conservation Fund (LWCF) are examples of federal government programs that have long collected revenues, amounting to billions of dollars over the decades, raised from (in the case of Duck Stamps) waterfowl hunters and (in the case of LWCF) royalties on Outer Continental Shelf offshore oil and gas development. These funds have been used to acquire millions of acres valuable habitats and land for habitat conservation, park, and historic preservation purposes.[201]

  In the case of the GYE, Wilkinson recommends "creating a war chest that enables land trusts and other conservation entities to pay ranchers and farmers to stay on the land, protect habitat and open space and prevent key parcels from being bought up and subdivided." Possible new sources of such funding are: 1) **real estate transfer tax**, "a modest tax applied whenever real estate is bought and sold." Wilkson notes that a modest tax of just 1 percent would eventually generate hundreds of millions of dollars that be used for conservation purposes; 2) **backpack tax**, "a tax that would be levied on all outdoor products, from apparel to backpacks, skis and other recreation gear, would generate billions over time." It is fitting that users of the Great Outdoors should help fund preservation of the landscapes and wildlife that inspire and attract them; 3) **modest enplanement fees**, under which arriving and departing airports in Bozeman and Jackson, the two busiest in Montana and Wyoming, respectively, would pay a modest surcharge. With a volume of 1.5 million passengers annually, $5 arrival and departure surcharges could generate $15 million to be used for land and habitat conservation.

- Allow Transfer of Development Rights (TDR): TDR is a widely-used "zoning technique that conserves land by redirecting development that would otherwise occur on the land (the sending area) to a receiving area suitable for denser development. The technique operates so that owners in the sending area can be compensated for their redirected development rights."[202] In the case of the GYE, the relevant state legislatures would authorize TDR for rural landowners to not develop important wildlife habitat and migration corridors, for example. According to Wilkinson, "it would also allow

[201] U.S. Fish and Wildlife Service. 2024. Duck Stamps. Available at: https://www.fws.gov/service/duck-stamps. No date. National Park Service. 2024. Land and Water Conservation Fund. Available at: https://www.nps.gov/subjects/lwcf/index.htm.
[202] WeConservePA. No date. Transfer of Development Rights. Accessed 8-3-2024 at: https://library.weconservepa.org/guides/12-transfer-of-development-rights.

rural landowners to consolidate subdivision lines and cluster development in ways that prevent sprawl."

- Avoid Building in Wildland-Urban Interface (WUI): The WUI includes areas at the edge between developed lands and wildlands; homes in the WUI are particularly vulnerable to wildfire in the Rocky Mountain West. Half of the U.S. Forest Service budget is spent fighting wildland fires and the great preponderance of these costs is spent on protecting structures on private lands in forested areas. Restrictions on home-building in the WUI would be similar to building restrictions in floodplains, where structures are predictably vulnerable to flood events; the public should not be subsidizing and thus enabling these risky private endeavors in inherently exposed areas. Reduction of building in the WUI would reduce unnecessary and unfair public costs even as it helps cut down on fragmentation of wildlife habitat.

- Eliminate Death Taxes for Conservation-Minded Ranchers: Wilkinson: "The next of kin of ranchers and farmers incur death taxes that often prevent them from being able to stay on the land and be creative with conservation options. Allow death taxes to be eliminated if families and corporate ag entities put their property into conservation easements."

- Embrace Urban Growth Boundaries: In NumbersUSA's 2020 report on urban sprawl in Oregon, we wrote: "In 1973 the Oregon state legislature passed a landmark statewide comprehensive land use planning law (SB 100). Among other mandates, SB 100 required each existing municipality in the state to establish an urban growth boundary (UGB), in effect drawing a line in the sand (or through forests, farms, and ranches, in the case of Oregon), beyond which urbanization could not march willy-nilly – at least not without a conscious, informed, publicized decision. Each of Oregon's 241 cities and towns of 2,500 or more residents is surrounded by an urban growth boundary. Portland's UGB was the first established in 1979."

  Wilkinson writes that UGB's concentrate growth and help protect surrounding farms and forests outside of the UGB. UGB's yield greater predictability for developers, help local officials better plan for growth, and lower the cost of infrastructure, utilities, and public services like law enforcement, fire protection, emergency response, road maintenance, water and sewer systems. Growth does not pay for itself and lower-density sprawling development imposes even greater costs on existing residents.

- Consolidate Regional Management: Wilkinson advocate combining national parks, national forests, and BLM lands into one federal lands management region united under a bioregional strategy. Federal agencies, gateway communities, and counties would be "financially incentivized to work together."

- Hire Wildlife Ecologists to Guide Growth: Professional wildlife ecologists who are specialists in large landscape conservation would be tapped to "provide honest assessments on impacts of proposed development and help educate elected officials, members of planning staffs, and the public about the location of key wildlife habitat."

- Planning, Info Sharing Between GYE Towns, Counties: Wilkinson advocates initiating routine planning and information-sharing meetings at least annually between communities and counties in the GYE undergoing rapid population growth. "There's a lot of intelligence and hard lessons that could be shared."

- Pass Open Space Bonds and Support Local Land Trusts: Land trusts or land conservancies are non-profit, community-based organizations that actively work to permanently conserve land, including habitat for plants and wildlife.[203] Conservation land trusts acquire and steward land or help facilitate conservation easements on private lands.[204] Various land trusts work actively in the GYE, and these deserve our support.

- State Legislatures Need to Get Out of the Way: Legislatures in the three GYE states (Idaho, Montana, Wyoming) have hindered the ability of local GYE communities to tax millions of visitors and tourists who generate impacts.

As can be seen from the above, there are many measures and planning tools that can be brought to bear at the local, regional, and state levels to manage growth and tame some of its ecosystem effects. These require ample and sustained political and public support at those levels, and while they can mitigate some of the adverse impacts of perpetual population growth on the GYE, they cannot stop or reverse all of them. If, hypothetically, the population growth trends of recent decades were to continue indefinitely and all of these new residents – and the facilities and infrastructure needed to accommodate and service them – were able to be contained within existing urban boundaries, i.e., if no new sprawl were to occur (which is highly unlikely even in the short term and all but impossible over the long term), the increased population size of the GYE would still impose a greater ecological burden on its wildlife resources just by the increase in vehicular traffic and greater visitation and congestion at recreation sites alone.

Thus, local and regional approaches alone, while vitally important and worthy of conservationists' support, will not safeguard the GYE's unique wildlife heritage in the face of unrelenting population growth in the 20 counties we have studied in this report, or in the face of relentless national population growth that indirectly exacerbates local and regional GYE growth pressures.

[203] Land Trust Alliance. 2024. What is a land trust? Accessed 8-4-2024 at: https://landtrustalliance.org/why-land-matters/land-conservation/about-land-trusts.
[204] WeConservePA. No date. What is a land trust? Accessed 8-4-2024 at: https://library.weconservepa.org/guides/150-what-is-a-land-trust.

4.2.2 National Approaches to Slow GYE Population Growth

Beyond the short term, local GYE officials supportive of growth control and management can only hope to slow population growth and sprawl in their jurisdictions if the national population continues to increase by some 3.0 to 3.5 million additional residents each year, which extrapolates to 30 to 35 million per decade. These additional residents – both native-born and foreign-born, will all settle somewhere, inevitably leading to additional sprawl and development as far and as long as the eye can see. Over the coming decades, some of these added tens of millions will choose to settle in the nation's "last best places" such as Idaho, Montana, and Wyoming – and the Greater Yellowstone Ecosystem in particular – as reflected in the region's current rapid rate of growth (double to triple the national rate).

In essence there are only three sources of national population growth: native fertility (in conjunction with slowly increasing life spans), immigration, and immigrant fertility. We know the following general information about their contributions to long-term U.S. population growth:

- Native fertility: At approximately 1.6 births per woman, the total fertility rate (TFR) of the United States is well below the replacement rate of 2.1 and has not been a source of long-term population growth in the U.S. since 1971, more than half a century ago. Total fertility rates for the main series in the U.S. Census Bureau's most recent population projections for the 2025-2100 period vary between 1.63 and 1.54.[205]

- Immigration and Immigrant Fertility: The sole source of long-term population growth in the United States is immigration, due both to new immigrants (now arriving, under the current administration, at about ten times higher than the "replacement rate," where immigration equals emigration) and to immigrants' fertility, which despite noteworthy declines in recent decades, has remained above replacement level and above native fertility.

Thus, direct long-term population growth in the United States and indirectly in the GYE is in the hands of federal lawmakers, executive branch, and policy-makers, not America's women, mothers, and families. It is they who have increased the annual intake and settlement of immigrants from one-quarter million in the 1950s and 1960s to over a million since 1990, fluctuating between one million and nearly two million, once net illegal immigration is included. More recently, under the Biden Administration's border policies, millions more economic migrants coached into making dubious or fraudulent claims of political asylum have essentially been invited into the country as "inadmissible aliens" and paroled into the

[205] U.S. Census Bureau. 2023. Methodology, Assumptions, and Inputs for the 2023 National Population Projections. Available online at: https://www2.census.gov/programs-surveys/popproj/technical-documentation/methodology/methodstatement23.pdf.

interior. Until the flow of immigration, and the unrelenting national population growth it drives, is lowered, even the best local plans and political commitment will be unable to stop or contain sprawl. Any serious efforts to halt the permanent, ongoing loss of open space, wildlife habitat, and farmland in the GYE must include reducing the rate of U.S. population growth, which perforce necessitates lowering the enormous volume of immigrants entering the country year after year, unless Americans and immigrants were to submit to lowering our current already sub-replacement-level fertility even lower to a one-child per woman average.

Figures 4-4 and 4-5 present U.S. population projections to the year 2100 using a population projection tool developed specifically for NumbersUSA, and based on U.S. Census Bureau methodology and initial demographic data. This tool uses the cohort-component method to generate population projections for the United States under various assumptions regarding future fertility rates, life expectancy, and annual net migration levels (immigration into the country minus emigration from it). It is based on the US Census Bureau's "Methodology, Assumptions, and Inputs for the 2023 National Population Projections" and their most recent data sets as of July, 2024.[206]

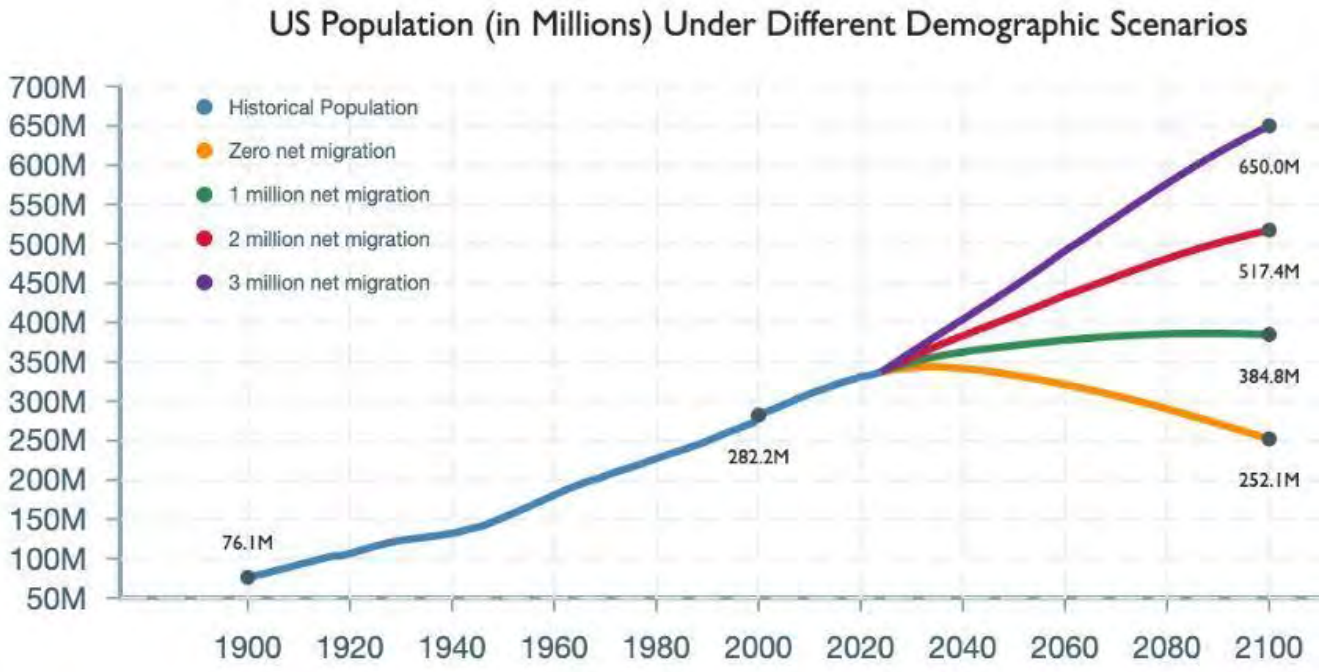


Figure 4-4. U.S. Population Projections to 2100 Under Different Assumptions

The projections in **Figures 4-4 and 4-5** use the Census Bureau's 2023 "main series" projection values for total fertility rates, life expectancy, and net migration between 2025 and 2100. Total fertility rates for the main projection series during this period vary between 1.63 and 1.54. Life expectancy varies between 76 and 86 for men and 81 and 88 for

[206] Ibid.

women. In the Bureau's own projection, annual migration levels vary between 853,000 and 976,000 between 2025 and 2100, but these are far below actual migration levels of the last few years. In **Figure 4-4**, when net migration is set at 3 million, close to current levels of net migration under the Biden administration, the U.S. population grows to 650 million by 2100, an increase of more than 310 million or 91 percent from the present population. At 1 million net migration, closer to the recent average until the boom of last several years, our population would still grow to 385 million by 2100, an increase of about 45 million new residents net, but at least it would have stabilized.

A still more sustainable immigration policy would be the approximately half-million/year of legal immigrants, plus more serious efforts to reign in illegal immigration, recommended in 1995 by the bi-partisan U.S. Commission on Immigration Reform, established by President Clinton and chaired by former Congresswoman Barbara Jordan (D-TX). That would roll annual immigration back to around the level that was the norm as recently as the 1980s.

Figure 4-5 looks at the long-term consequences of implementing the 1995 Jordan Commission recommendations (as noted, approximately 500,000 annual net migration), the average immigration rate during the Trump administration (approximately 1 million net), and the Biden administration average (about 2 million net). Under the former, U.S. population would peak by about 2040 and gradually decline to 318 million by 2100; under the Trump average, it would grow to 385 million but stabilize, while under the Biden average, it would grow to 517 million and still be increasing rapidly in the year 2100.

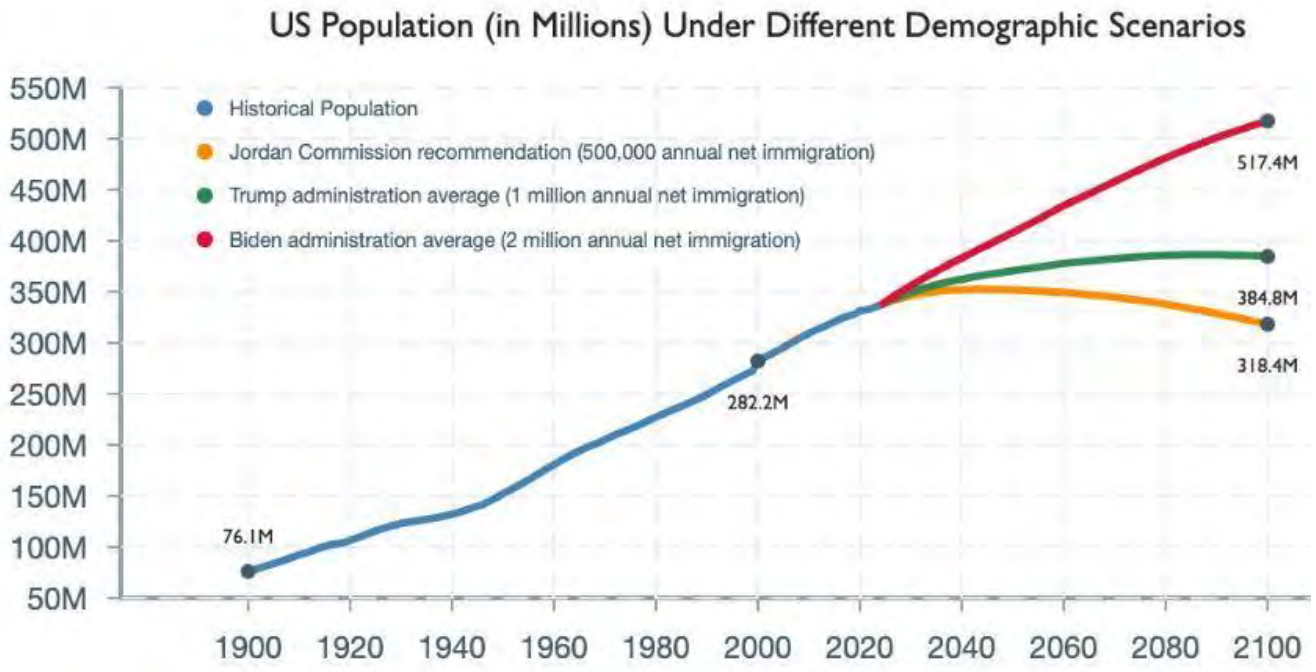


Figure 4-5. U.S. Population Projections to 2100 under Jordan Commission Recommendations and Trump and Biden Average Annual Immigration Rates

A survey of 1,128 likely U.S. voters conducted by Rasmussen and NumbersUSA on July 29-29, 2024, in conjunction with this study, found that reducing immigration was a relatively popular policy choice among most when linked with the goal of slowing down U.S. population growth (see Appendix D for the full survey questions and results). 57 percent of America's likely voters responded that they would prefer that the "federal government reduce annual immigration to slow down population growth…"

> The main source of national population growth is immigration from other countries. Should the federal government reduce annual immigration to slow down population growth, keep immigration and population growth at the current level, or increase annual immigration and population growth?
>
> 57% Reduce
> 28% Current level
> 7% Increase
> 8% Not sure

A parallel survey of 829 Idaho, Montana, and Wyoming likely voters in particular, conducted from July 28-30, 2024 by Rasmussen and NumbersUSA, also in conjunction with this study, found that reducing immigration was equally a popular policy choice among most when linked with the goal of slowing down U.S. population growth (see Appendix E for the full survey questions and results). Fifty-nine percent of Idaho, Montana, and Wyoming likely voters (compared with 57% of U.S. voters overall) responded that they would prefer that the "federal government reduce annual immigration to slow down population growth…"

> The main source of national population growth is immigration from other countries. Should the federal government reduce annual immigration to slow down population growth, keep immigration and population growth at the current level, or increase annual immigration and population growth?
>
> 59% Reduce
> 27% Current level
> 7% Increase
> 7% Not sure

We also asked Idaho, Montana, and Wyoming likely voters about E-Verify, which was supported by more than three-quarters (77%):

> Currently, in addition to the million legal immigrants each year, about 2.5 million inadmissible foreign citizens overstay a visa, avoid the border patrol, or are released into the country every year. In trying to control illegal immigration, should the government mandate that all employers use the federal electronic E-Verify system to help ensure that they hire only legal workers for U.S. jobs?
>
> 77% Yes
> 9% No
> 14% Not sure

Figure 4-6. Billboards advertising a piece of paradise in Paradise Valley, Montana, north of Yellowstone National Park
Photo credit: Leon Kolankiewicz

Among likely voters who live within three hours of Yellowstone or Grand Tetons National Parks – that is, the residents of or closest neighbors to the GYE – an even higher percentage supported use of E-Verify in responding to the same question. Supporters of E-Verify outnumbered opponents by a 10 to 1 margin.

80% Yes
8% No
14% Not sure

In our late July 2024 survey of 829 Idaho, Montana, and Wyoming likely voters, included as Appendix E, we queried attitudes about population size and growth rates and what they might do to the GYE. Fifty-three percent responded that development of an additional 360 square miles of wildlife habitat and farmland to accommodate projected population growth would make Greater Yellowstone worse:

If recent population growth and development trends continue to 2060, the population of Greater Yellowstone would grow by another 40 percent. Another 360 square miles of wildlife habitat and farmland would be developed to accommodate this growth. Would this make Greater Yellowstone better, worse, or not much different?

21% Better
53% Worse

16% Not much difference
11% Not sure

Sixty-eight percent believed that this projected growth and development would have a very or somewhat negative effect on Greater Yellowstone's wildlife:

Would the projected future population growth and development have a very negative effect on Greater Yellowstone's wildlife, a somewhat negative effect, a generally neutral effect, a somewhat positive effect, or a very positive effect?

21% Very negative
47% Somewhat negative
16% Neutral
7% Somewhat positive
6% Very positive
4% Not sure

Almost seven in ten residents of Idaho, Montana, and Wyoming responding to our 2024 survey expressed support for lowering current immigration rates. They might be gratified to know that a national commission made similar recommendations nearly three decades ago. The President's Council on Sustainable Development in 1996 – established by President Clinton and inspired by the 1992 Earth Summit in Rio de Janeiro, Brazil – recommended that the United States stabilize its population in order to pursue environmental sustainability. It called for reducing immigration to a level that would allow for a stable population. At current U.S. fertility rates, that would necessitate immigration rates roughly comparable to those recommended by the Jordan Commission at about the same time, half a million a year or less.

The Population and Consumption Task Force of the Council on Sustainable Development concluded in 1996: "This is a sensitive issue, but reducing immigration levels is a necessary part of population stabilization and the drive toward sustainability."[207]

It is important to emphasize that the additional sprawl that occurs because of high immigration levels has nothing to do with the quality of immigrants as people or individuals but everything to do with the quantity of population growth that occurs because of immigration. This can be seen by simply observing that towns, cities, and states with higher population growth have higher amounts of sprawl, regardless of whether most of the incoming new residents come from another region of the United States or from another continent.

[207] President's Council on Sustainable Development. 1996. *Population and Consumption Task Force Report.* 1996. Co-Chairs: Dianne Dillon-Ridgley, Co-Chair, Citizen's Network for Sustainable Development and Timothy E. Wirth, Under Secretary for Global Affairs, U.S. Department of State.

In our 2003 national-level study, we devoted several pages to our findings on ways in which an Urbanized Area's population growth from immigrants would have either a greater or lesser effect on sprawl than a net population growth of the same size from U.S.-born residents. We could find no precise method of quantification but concluded that the various factors largely balanced each other.

A key way in which growth from immigration has a somewhat smaller effect on sprawl is the lower average income level and, thus, a lower consumption level of the average immigrant. But we found that an assumption about immigrants having less of an effect because they presumably prefer central cities to suburbs was false. The majority of immigrants now live in suburbs, where the sprawl occurs.[208] And the adult children of immigrants were found to be just as likely to eschew living in core cities as the adult children of natives. In fact, the lower incomes were inducing immigrants to move to the edges of cities and even to ex-urban or rural settlements beyond the cities to find more affordable housing.

As described in Section 2.3.1 on the sources of Idaho's, Montana's, and Wyoming's population growth, immigration from foreign countries, while comprising just 17 percent of the states' population growth in recent decades, indirectly influences that growth in a major way not involving the immigrants actually settling in the state. Because California – the single largest domestic source of these three states' and the GYE's internal or domestic migrants – has experienced so many ill effects from its massive population, for years Idaho, Montana, Wyoming, and Greater Yellowstone have received a large number of California "refugees" fleeing the ill effects of this overpopulation. Because nearly all of California's population growth – until it stopped growing several years ago – has been due to immigration, much of California's hemorrhaging into the Northern Rockies, Pacific Northwest, Southwest, and elsewhere must be considered as another consequence of the quadrupled level of annual federal immigration since 1970.

On a local level, the sprawl pressures of population growth are similar regardless of where the new residents originate. But very few towns and cities are likely to be able to subdue population growth and related sprawl and habitat loss if the federal government continues policies that add 30 million or more people to the country decade after decade, all of whom have to settle somewhere. The reality – which can only be mitigated but not eliminated by good planning, enlightened zoning, urban growth boundaries, or Smart Growth – is that all growing human settlements, large or small, already occupy or will occupy lands that were formerly or still are productive agricultural lands and/or irreplaceable wildlife habitats. This is true whether in Greater Yellowstone or New Jersey's Pine Barrens.

[208] Jill H. Wilson and Audrey Singer. October 2011. *Immigrants in 2010 Metropolitan America: A Decade of Change*. Metropolitan Policy Program at Brookings. Available online at: https://www.brookings.edu/research/immigrants-in-2010-metropolitan-americaa-decade-of-change/

This is not a sustainable path forward, and it is not one we believe that fully informed and engaged Americans and Yellowstonians would voluntarily choose. After all, consider these responses of Americans and Yellowstonians to two of the questions in particular, posed in our late July 2024 public opinion survey:

Survey of 1,128 U.S. likely voters conducted July 28-29, 2024:

> Does the United States have a responsibility to the rest of the world to preserve the Greater Yellowstone Ecosystem or is preserving this ecosystem not a matter of global concern?
> 70% Yes
> 20% No
> 10% Not sure

Survey of 829 Idaho, Montana, and Wyoming likely voters conducted July 28-30, 2024:

> Does the United States have a responsibility to the rest of the world to preserve the Greater Yellowstone Ecosystem or is preserving this ecosystem not a matter of global concern?
> 76% Yes
> 14% No
> 10% Not sure

> When considering why you live in this region, which of the following reasons is most important to you? Please listen to the entire list before responding.
>
> 37% Natural beauty and wildlife
> 6% Recreation opportunities
> 12% Low crime
> 10% Affordable housing and cost of living
> 18% Family ties
> 11% Some other reason
> 6% Not sure

For residents of Idaho, Montana, and Wyoming, "natural beauty and wildlife" was by far the single most important reason chosen for living in the region, even above recreational opportunities, low crime, affordable housing and cost of living, and family ties. For the residents and neighbors of the GYE itself, the responses are also illuminating:

> When considering why you live in this region, which of the following reasons is most important to you? Please listen to the entire list before responding.
> 44% Natural beauty and wildlife
> 6% Recreation opportunities
> 13% Low crime

9% Affordable housing and cost of living
16% Family ties
8% Some other reason
4% Not sure

An even higher percentage (44%) of GYE residents and neighbors selected "natural beauty and wildlife," almost three times as much as the next closest choice, "family ties" (16%).

Given these priorities and values, we reiterate our conclusion above: that most fully informed and engaged Americans and Yellowstonians acknowledge reasonable limits both to development and to the national, regional, and local population growth that is its primary driver.

Appendix A
Glossary

Central Place – The Census Bureau delineates an urbanized area (UA) as one or more "central places" and the "urban fringe" (the adjacent densely settled surrounding territory) that together contain a minimum of 50,000 residents. A central place functions as the dominant center of each UA. The identification of a UA central place permits the comparison of this dominant center with the remaining territory in the UA. A central place generally is the most densely populated and oldest city in a metropolitan area.

Density – Shorthand for population density, or the number of residents per unit area, usually measured in number of residents per acre or square mile. Density is the mathematical inverse or opposite of land consumption per person (per capita). For example, a density of five persons or residents per acre equals 3,200 per square mile. This in turn equals a per capita land consumption of 0.2 acre per person.

Developed Land – As defined by the U.S. Department of Agriculture's Natural Resources Conservation Service in its National Resources Inventories (NRIs), issued every five years since 1982, built-up or paved land that is at least one-quarter acre in area. Developed land can include built-up areas outside of urbanized areas, towns, or cities. The NRI Developed Land category includes: (a) large tracts of urban and built-up land; (b) small tracts of built-up land less than 10 acres in size; and (c) land outside of these built-up areas that is in a rural transportation corridor (roads, interstates, railroads, and associated rights-of-way).

Foreign Born – Describing a person born in a country other than the United States. Excludes those born abroad to American parents. Can be used as a noun or an adjective.

High-Density – A large number of residents per unit area, usually measured in terms of residents per acre or square mile. While there is no one precise, agreed-upon criterion or threshold of high-density residential development, a density of approximately 5,000 per square mile would be considered relatively high-density.

Holdren Method – Mathematical methodology for determining the percentages of Overall Sprawl attributable to Per Capita Sprawl and Population-driven Sprawl, in other words, to increasing per capita land consumption (decreasing population density) and to population growth.

Hop – a connection from one urban area core to other qualifying urban territory along a road connection of half a mile (0.5 mile) or less in length; multiple hops may be made along any given road corridor. This criterion recognizes that alternating patterns of residential development and non-residential development are a typical feature of urban landscapes.

Immigration – Permanent movement (i.e., settlement) of a foreign-born person to the

United States either with permission from U.S. authorities (legal immigration) or without such permission (illegal immigration).

Immigrant Fertility – Fertility of foreign-born immigrants to the United States, usually expressed in terms of the Total Fertility Rate (TFR) of women, which is the average total number of children born to women of a defined group during the course of their reproductive years.

Jump – a connection from one urban area core to other qualifying urban territory along a road connection between 0.5 mile and 2.5 miles in length; only one jump may be made along any given road connection.

Low-Density – Relatively low population density, or low number of residents per unit area (acre or square mile). Urban / suburban densities of 1,000-2,000 per square mile would be considered low-density, though still enough to qualify as urban.

Native Born – A person born in the United States.

Natural Habitat – That portion of rural or undeveloped land that consists of upland and bottomland forests, woodlands, savanna, scrub-shrub, natural grasslands or prairie, wetlands (marshes, swamps, bogs), ponds, watercourses, deserts, alpine meadow and tundra. Natural habitats support wildlife and provide other ecosystem services. They may be in public or private ownership.

New Urbanism – A movement that sees urban centers as potentially vibrant communities that can mix and harmonize residential and commercial uses in clever and innovative ways to make cities satisfying and safe places to live and work. New urbanism supports such concepts as higher density in urban cores, mixed uses, mass transit, close proximity of dwellings to workplace, walkable communities, bicycle lanes, community gardens, and others. New urbanism sees relentless sprawl in America as one consequence of the abandonment of our central cities.

Per Capita Land Consumption – Average amount of land used by each resident of an urbanized area or developed area. Includes not just residential land but all developed land used by urban residents, including commercial, institutional, small park, transportation (e.g., streets, roads, railroads, freeways, parking lots), and industrial land uses.

Open Space – Land lacking significant built structures or pavement. Includes rural and undeveloped lands and natural habitat outside of urban boundaries; also includes larger natural areas, parks and green space within urban areas, such as golf courses and extensive lawns or gardens. Yards or wooded lots on quarter-acre lots in residential areas would not qualify as open space.

Overall Sprawl – See "sprawl" below. Overall sprawl is the sum of Per Capita Sprawl and Population-driven sprawl [the total amount of open space converted to development over a period of time].

Per Capita Sprawl – Sprawl that is driven by increase in per capita land consumption, that is, land consumption per resident, of an urbanized area, developed area, city or town; Per Capita Sprawl is measured in terms the increase in acres or square miles of developed or urbanized acres of land per person. Per Capita Sprawl and population-driven sprawl add up to 100 percent of Overall Sprawl.

Population-driven Sprawl – Sprawl that is driven by increase in the population of an urbanized or developed area. Population-driven and Per Capita Sprawl add up to 100 percent.

Population Growth – Increase in the number of residents of a given area, such as a town, city, urbanized area, state, or country over time. Population growth is equal to the total births of native-born residents minus the total deaths of native-born residents minus the emigration of native-born residents PLUS total immigration of the foreign born plus births to the foreign born minus deaths of the foreign born minus emigration of the foreign born (i.e., return to the country of their birth or a third country). In recent decades, annual population growth in the United States as a whole has been running about 2.5 million to 3 million per year on average, or roughly 30 million per decade.

Rural Land – Undeveloped lands outside of urban areas, including farmland, pastureland, rangeland, and natural or semi-natural habitats, like forests, woodlands, wetlands, grasslands or prairie, and deserts. Rural lands may be flat or mountainous, and publicly or privately owned.

Smart Growth – The use of a variety of land-use, planning, statutory, regulatory, taxing, and other tools by federal and state governments and local jurisdictions (municipalities) to reduce haphazard, low-density, and poorly planned development in a given region.

Smart Growth Movement – A loose, eclectic coalition of environmentalists, local growth-control activists, New Urbanists, municipal and regional planners, think-tanks, the federal government and many state governments, and even some home-builders united by their interest in slowing the rate of sprawl, and making existing communities more sustainable and livable.

Sprawl – As defined in this study, the increase in the physical area of a town or city over time – outward expansion – as undeveloped or rural land at its periphery is permanently converted to developed or urbanized land as population and/or per capita land consumption grow. More specifically, in this study, sprawl is 1) the increase in the area of the Census Bureau's Urbanized Areas, as delineated every 10 years in the decadal censuses, and/or 2) the increase in the area of a state's area of Developed Land, as determined by the Natural Resources Conservation Service.

Suburbs – Residential or commercial zones on the outskirts of a central city or town; generally corresponds to "urban fringe." Tend to have a lower population density than the central place or urban core, though not always, as when downtown districts are dominated by office, institutional, and commercial zones.

Urban Core – Used in this report as another description for "central location" as defined by the Census Bureau. The urban core is the entire city that anchors a metropolitan area, and usually is

at its center. It generally is the oldest, most densely populated and most built-up portion of an urbanized area.

Urban Fringe – Built-up areas near the edge of an urbanized area, generally with lower population density than the urban core; generally corresponds to the inner and outer suburbs of a town or city.

Urban Sprawl – See "sprawl."

Urbanized Area – As defined by the U.S. Census Bureau, an area of contiguous census blocks or block groups with a population of at least 50,000 and an average population density of at least 1,000 residents per square mile.

Appendix B
Calculating Per Capita Land Consumption

The per person land consumption in each state or Urbanized Area can be expressed as:

(1) $a = A / P$

where:

a = area of developed or urbanized land area for the average resident
A = Area of total developed or urbanized land in a state
P = Population of that state

For example, in 2015 Arizona had 6,758,251 residents and approximately 2,108,600 developed acres. Thus, per capita developed land use for all purposes was around 0.31 acre (slightly more than a third of an acre) per resident.

The land used per person is the total developed or urbanized land area divided by the total number of people. This is the inverse of population density, which is the number of people per unit area of land. When per capita land consumption goes up, density goes down; when per capita land consumption goes down, density goes up.

The developed land area of any given state can be expressed as:

(2) $A = P \times a$

This can be stated as: the total developed area in square miles (or acres) of a state can be simply expressed or "factored" into the product of the Population of the state (*viz*., P) multiplied by the per capita urban land consumption (*viz*., a). This second equation (2) is the basis for attributing or apportioning the shares of sprawl (viz. growth in A) back onto two contributing factors, the growth in P and the growth in a.

Appendix C
Apportioning Shares of Overall Sprawl Between Population Growth and Per Capita Sprawl

A methodology for quantifying the respective contributions of population growth and changes in per capita consumption of any type of resource use was outlined in a 1991 paper by physicist John Holdren ("Population and the Energy Problem." *Population and Environment*, Vol. 12, No. 3, Spring 1991). Although Dr. Holdren's 1991 paper dealt specifically with the role of population growth in propelling the increase in U.S. energy consumption, the same methodology can also be applied to many types of population and resource consumption analyses.

In the case of sprawl, the natural resource under consideration is rural land, namely the expansion over time in the total acreage of rural land urbanized or converted into developed land and subsequently used for urban purposes, such as for housing, commerce, retail, office space, education, light and heavy industry, transportation, and so forth.

As stated in Appendix B, the total land area developed in a city (urbanized area) or state can be expressed as:

(1) $A = P \times a$

Where:

A = Area of total are (in acres or square miles) of development in city or state
P = Population of that city or state
a = area of city or state used by the average resident (per capita land use)

Following the logic in Holdren's paper, if over a period of time ⊗t (e.g., a year or a decade), the population grows by an increment ⊗P and the per capita land use changes by ⊗a, the total urbanized land area grows by ΔA, expressed as:

(2) $A + \Delta A = (P + \Delta P) \times (a + \Delta a)$

Subtracting eqn. (1) from eqn. (2) and dividing through by A to compute the relative change (i.e., $\Delta A/A$) in urbanized land area over time interval Δt yields:

(3) $\Delta A/A = \Delta P/P + \Delta a/a + (\Delta P/P) \times (\Delta a/a)$

Now equation (3) is quite general and makes no assumption about the growth model or time interval. On a year-to-year basis, the percentage increments in P and a are small (i.e., single digit percentages), so the second order term in equation (3) can be ignored. Hence following the Holdren paradigm, eqn. (3) states that the percentage growth in urbanized land area (viz., 100 percent x $\Delta A/A$) is the sum of the percentage growth in the population (100

percent x $\Delta P/P$) plus the percentage growth in the per capita land use (100 percent x $\Delta a/a$). Stated in words, equation (3) becomes:

(4) *Overall percentage land area growth = Overall percentage population growth + Overall percentage per capita growth*

In essence, the Holdren methodology quantifies population growth's share of total land consumption (sprawl) by finding the ratio of the overall percentage change in population over a period of time to the overall percentage change in land area consumed for the same period. This can be expressed as:

(5) $$\textit{Population share of growth} = \frac{\textit{(Overall percentage population growth)}}{\textit{(Overall percentage land area growth)}}$$

The same form applies for per capita land use:

(6) $$\textit{Per capita land use share of growth} = \frac{\textit{(Overall \% per capita land use growth)}}{\textit{(Overall \% land area growth)}}$$

The above two equations follow the relationship based on Prof. Holdren's equation (5) in his 1991 paper. A common growth model follows the form (say for population):

(7) $$P(t) = P_0(1 + g_p)t$$

Where $P(t)$ is population at time t, P_0 is the initial population and g_p the growth rate over the interval. Solving for g_p the growth rate yields:

(8) $$\ln(1 + g_p) = (1/t) \ln(P(t)/P_0)$$

Since $\ln(1 + x)$ approximately equals x for small values of x, equation (8) can be written as:

(9) $$g_p = (1/t) \ln(P(t)/P_0)$$

The same form of derivation of growth rates can be written for land area (A) and per capita land use (a)

(10) $$g_A = (1/t) \ln(A(t)/A_0)$$

(11) $$g_a = (1/t) \ln(a(t)/a_0)$$

These three equations for the growth rates allow the result of equation (4) to be restated as:

(12) $$gP + g_a = g_A$$

Substituting the formulae (equations 9 through 11) for the growth rates and relating the initial and final values of the variables P, a and A over the period of interest into equation (12), the actual calculational relationship becomes:

(13) ln (*final population / initial population*) + ln (*final per capita land area / initial per capita land area*) = ln (*final total land area / initial total land area*)

In other words, the natural logarithm (ln) of the ratio of the final to initial population, plus the logarithm of the ratio of the final to initial per capita land area (i.e., land consumption per resident), equals the logarithm of the final to the initial total land area.

In the case of, say, the state of Arizona from 1982 to 2015, this formula would appear as:

(14) ln (7,044,008 *residents* / 2,889,860 *residents*) + ln (*0.298 acre per resident / 0.340 acre per resident*) = ln (*2,098,900 acres / 982,700 acres*)

Computing the ratios yields:

(15) ln (2.4375) + ln (0.8765) = ln (2.1359)

0.8910 + (-0.1321) = 0.7589

Then, applying equations (5) and (6), the percentage contributions of population growth and per capita land area growth are obtained by dividing (i.e., normalizing to 100 percent) each side by 0.7589:

(16) $\frac{0.8910}{0.7589} - \frac{0.1321}{0.7589} = \frac{0.7568}{0.7589}$

Performing these divisions yields:

(17) 1.17 - 0.17 = 1.0

Thus, we note that in the case of Arizona from 1982 to 2015, the share of sprawl due to population growth was 117 percent [100 percent x (0.8910 / 0.7589)], while declining density (i.e., an increase in land area per capita) accounted for -13 percent [100 percent x (-0.1321 / 0.7589)]. Note that the sum of both percentages equals 100 percent.

In the main body of this report we modify this gross state-wide percentage of sprawl related to population growth by using a county-by-county weighting approach. This approach accounts for the sprawl that occurs in each county and lends a proportionately greater weight to those counties with greater amounts of sprawl. In essence, sprawl in counties around Boise, for example, should not be attributed to population growth in counties around Coeur d'Alene. In this method, the amount of sprawl related to population growth in each county is summed for all 44 counties in the state. This sum or aggregate is then divided by the total amount of sprawl in the state. Using this procedure, 77 percent of the sprawl in Idaho between 1982 and 2017 is shown to be associated with population growth, which the authors believe is a more accurate rendering of population growth's role than 111 percent, which exaggerates population's role, and implies that all sprawl (and then some) in Idaho is related to population growth; this is not the case.

Appendix D
Survey of 1,128 U.S. Likely Voters
Conducted July 28-29, 2024
By Rasmussen Reports and NumbersUSA

1. Biden Approval

   27% Strongly approve
   18% Somewhat approve
   10% Somewhat disapprove
   44% Strongly disapprove
    2% Not sure

2. Have you ever heard of Yellowstone National Park?

   93% Yes
    5% No
    2% Not sure

3. Have you ever visited Yellowstone or Grand Tetons National Parks?

   35% Yes
   64% No
    2% Not sure

   Answered by 735 respondents who haven't visited Yellowstone:

4. Would you like to visit Yellowstone or Grand Tetons National Parks?

   68% Yes
   20% No
   12% Not sure

   Answered by 890 respondents who have visited or want to visit Yellowstone:

5. How important is the wildlife to those park visits? The main reason you visit, one of the two main reasons, important but not one of the top two reasons, or it is not an important reason to visit?

   23% Main reason
   51% Top two
   23% Important but not top two
    3% Not important
    0% Not sure

6. Are you aware that the Greater Yellowstone Ecosystem is unique in the Lower 48 States in still having all of its original large wildlife species, including grizzly bears, elk, bison, and wolves?

   63% Yes
   27% No
   10% Not sure

7. How important to you is it that large wildlife species continue to survive and flourish in the Greater Yellowstone Ecosystem?

   70% Very important
   25% Somewhat important
   4% Not very important
   1% Not at all important
   1% Not sure

8. Are you aware that the vast majority of large mammals in the Yellowstone-Tetons Parks rely upon surrounding PRIVATE lands to survive during at least part of the year?

   45% Yes
   39% No
   16% Not sure

9. Does the United States have a responsibility to the rest of the world to preserve the Greater Yellowstone Ecosystem or is preserving this ecosystem not a matter of global concern?

   70% Yes
   20% No
   10% Not sure

10. In recent decades, the population of the private lands of the Greater Yellowstone Ecosystem has increased by more than half. The nearly 200,000 additional residents contributed to the development of about 240 square miles of wildlife habitat and farmland. Are you very concerned, concerned, a bit concerned, or unconcerned about this trend?

    30% Very concerned
    44% Somewhat concerned
    17% Not very concerned
    6% Not at all concerned
    3% Not sure

11. If recent population growth and development trends continue to 2060, the population of Greater Yellowstone would grow by another 40 percent. Another 360 square miles of

wildlife habitat and farmland would be developed to accommodate this growth. Would this make Greater Yellowstone better, worse, or not much different?

23% Better
51% Worse
16% Not much difference
10% Not sure

12. A study of government data found that most U.S. farmland and natural habitat lost to development in the last decade was related to the country's population growing by 22 million people. The Census Bureau projects the population will grow by tens of millions more in the next 40 years. Would this type of population growth in YOUR area make it a better place to live, a worse place to live, or would it not make much difference?

    16% Better
    55% Worse
    21% Not much difference
     7% Not sure

13. The main source of national population growth is immigration from other countries. Should the federal government reduce annual immigration to slow down population growth, keep immigration and population growth at the current level, or increase annual immigration and population growth?

    57% Reduce
    28% Current level
     7% Increase
     8% Not sure

14. Currently the federal government adds about one million legal immigrants to the country each year. What annual level would you prefer:

    11% 2 million +
     9% 1.5 million
    23% 1 million
    20% 0.5 million
    25% 100k or less
    13% Not sure

15. Currently, in addition to the million legal immigrants each year, about 2.5 million inadmissible foreign citizens overstay a visa, avoid the border patrol, or are released into the country every year. In trying to control illegal immigration, should the government mandate that all employers use the federal electronic E-Verify system to help ensure that they hire only legal workers for U.S. jobs?

    75% Yes

10% No
15% Not sure

16. Do you feel an emotional or spiritual uplift from time spent in natural areas such as forests, wetlands, meadows, and mountains?

    74% Yes
    13% No
    13% Not sure

17. One way to accommodate continued population growth in Greater Yellowstone without losing as much natural habitat and farmland to development would be to increase population density by changing zoning and other regulations so more residents live in apartments, condos, and townhouses instead of single-family houses. Do you strongly favor, somewhat favor, somewhat oppose, or strongly oppose this kind of change?

    20% Strongly favor
    32% Somewhat favor
    19% Somewhat oppose
    17% Strongly oppose
    12% Not sure

18. Zoning, urban growth boundaries, and limiting the number of new hook-ups to sewage treatment systems are examples of planning or "smart growth" tools for accommodating population growth while attempting to reduce new development and sprawl from spreading further into the surrounding countryside. Do you favor using such planning tools as a means of limiting sprawl?

    53% Yes
    17% No
    30% Not sure

19. Do you favor paying higher property taxes to accommodate new residents and residential development into your community?

    17% Yes
    70% No
    13% Not sure

20. Where Do You Live?

    30% Urban
    49% Suburban
    20% Rural
     1% Not sure

21. Prefer To Live?

26% Urban
37% Suburban
34% Rural
3% Not sure

NOTE: Margin of Sampling Error, +/- 3 percentage points with a 95% level of confidence

Appendix E

Survey of 829 Idaho, Montana, and Wyoming Likely Voters
Conducted July 28-30, 2024
By Rasmussen Reports and NumbersUSA

1. Biden Approval

22% Strongly approve
15% Somewhat approve
11% Somewhat disapprove
50% Strongly disapprove
2% Not sure

1. Have you ever visited Yellowstone or Grand Tetons National Parks?

83% Yes
16% No
1% Not sure

Answered by the 138 respondents who had not visited Yellowstone:

2. Would you like to visit Yellowstone or Grand Tetons National Parks?

84% Yes
14% No
2% Not sure

Answered by the 691 respondents who have visited Yellowstone:

3. How many times have you visited Yellowstone National Park?

18% Once
53% 2 to 6 times
13% 7 to 12 times
16% More than 12 times
1% Not sure

Answered by the 691 respondents who have visited Yellowstone:

4. How often EACH YEAR do you tend to visit Yellowstone-Grand Tetons?

53% Never or < once per year
38% Once or twice
4% 3 to 6 times

1% 7 to 12 times
1% More than 12 times
3% Not sure

Answered by the 807 respondents who have visited or want to visit Yellowstone:

5. How important is the wildlife to those park visits? The main reason you visit, one of the two main reasons, important but not one of the top two reasons, or it is not an important reason to visit?

   26% Main reason
   53% Top two
   18% Important but not top two
   3% Not important
   1% Not sure

6. Are you aware that the Greater Yellowstone Ecosystem is unique in the Lower 48 States in still having all of its original large wildlife species, including grizzly bears, elk, bison, and wolves?

   83% Yes
   13% No
   4% Not sure

7. How important to you is it that large wildlife species continue to survive and flourish in the Greater Yellowstone Ecosystem?

   76% Very important
   19% Somewhat important
   3% Not very important
   1% Not at all important
   1% Not sure

8. Are you aware that the vast majority of large mammals in the Yellowstone-Tetons Parks rely upon surrounding PRIVATE lands to survive during at least part of the year?

   68% Yes
   23% No
   9% Not sure

9. In recent decades, the population of the private lands of the Greater Yellowstone Ecosystem has increased by more than half. The nearly 200,000 additional residents contributed to the development of about 240 square miles of wildlife habitat and farmland.

   36% Very concerned

39% Somewhat concerned
16% Not very concerned
5% Not at all concerned
4% Not sure

10. If recent population growth and development trends continue to 2060, the population of Greater Yellowstone would grow by another 40 percent. Another 360 square miles of wildlife habitat and farmland would be developed to accommodate this growth. Would this make Greater Yellowstone better, worse, or not much different?

    21% Better
    53% Worse
    16% Not much difference
    11% Not sure

11. Would the projected future population growth and development have a very negative effect on Greater Yellowstone's wildlife, a somewhat negative effect, a generally neutral effect, a somewhat positive effect, or a very positive effect?

    21% Very negative
    47% Somewhat negative
    16% Neutral
    7% Somewhat positive
    6% Very positive
    4% Not sure

12. The main source of Greater Yellowstone's population growth is people moving in from other states. Should local and state governments in Montana, Wyoming, and Idaho make it more difficult for people to move to the region from other states by restricting development?

    68% Yes
    17% No
    16% Not sure

13. The main source of national population growth is immigration from other countries. Should the federal government reduce annual immigration to slow down population growth, keep immigration and population growth at the current level, or increase annual immigration and population growth?

    59% Reduce
    27% Current level
    7% Increase
    7% Not sure

14. Currently the federal government adds about one million legal immigrants to the country each year. What annual level would you prefer:

    5% 2 million +
    12% 1.5 million
    20% 1 million
    18% 0.5 million
    31% 100k or less
    13% Not sure

15. Currently, in addition to the million legal immigrants each year, about 2.5 million inadmissible foreign citizens overstay a visa, avoid the border patrol, or are released into the country every year. In trying to control illegal immigration, should the government mandate that all employers use the federal electronic E-Verify system to help ensure that they hire only legal workers for U.S. jobs?

    77% Yes
    9% No
    14% Not sure

16. Does the United States have a responsibility to the rest of the world to preserve the Greater Yellowstone Ecosystem or is preserving this ecosystem not a matter of global concern?

    76% Yes
    14% No
    10% Not sure

17. Do you feel an emotional or spiritual uplift from time spent in natural areas such as forests, wetlands, meadows, and mountains?

    86% Yes
    8% No
    6% Not sure

18. One way to accommodate continued population growth in Greater Yellowstone without losing as much natural habitat and farmland to development would be to increase population density by changing zoning and other regulations so more residents live in apartments.

    24% Strongly favor
    31% Somewhat favor
    20% Somewhat oppose
    16% Strongly oppose
    10% Not sure

19. Zoning, urban growth boundaries, and limiting the number of new hook-ups to sewage treatment systems are examples of planning or "smart growth" tools for accommodating population growth while attempting to reduce new development and sprawl from spreading further into the surrounding countryside. Do you favor using such planning tools as a means of limiting sprawl?

    64% Yes
    15% No
    21% Not sure

20. Do you favor paying higher property taxes to accommodate new residents and residential development into your community?

    20% Yes
    69% No
    11% Not sure

21. When considering why you live in this region, which of the following reasons is most important to you? Please listen to the entire list before responding.

    37% Natural beauty and wildlife
     6% Recreation opportunities
    12% Low crime
    10% Affordable housing and cost of living
    18% Family ties
    11% Some other reason
     6% Not sure

22. How long have you lived in the region?

    47% Entire life
    16% Moved here over 30 years ago
    18% Moved here 10-30 years ago
     8% Moved here 5-9 years ago
     9% Moved here < 5 years ago
     2% Not sure

23. Do you live within a 3 hours' drive of Yellowstone or Grand Tetons National Park?

    50% Yes
    42% No
     8% Not sure

24. Do you live in a major city, the suburbs, a small city, a town or a rural area?

    39% Urban

18% Suburban
42% Rural
2% Not sure

25. Where would you prefer to live – in a major city, the suburbs, a small city, a town or a rural area?

35% Urban
11% Suburban
50% Rural
4% Not sure

NOTE: Margin of Sampling Error, +/- 3 percentage points with a 95% level of confidence

Appendix F
Advisors* to the 2001 study
"Weighing Sprawl Factors in Large U.S. Cities"

Urban Planning Oversight
Earl M. Starnes, *Ph.D., professor emeritus, urban and regional planning, University of Florida*
Eben Fodor, *urban planning consultant, Eugene (OR); author,* Better not Bigger: How to Take Control of Urban Growth and Improve Your Community
Gabor Zovanyi, *Ph.D., professor of urban planning*, *Eastern Washington University*
Robert Seaman, a*ssociate professor of environmental science, New England College; executive committee, American Society of Civil Engineers' Urban and Development Division*
Ruth Steiner, *Ph.D., professor of urban and regional planning, University of Florida*

Statistical Oversight
Alan J. Truelove, *Ph.D., statistician, retired professor, University of the District of Columbia*
B. Meredith Burke (1947-2002), *Ph.D., demographer*
Ben Zuckerman, *Ph.D.*, *professor of physics and astronomy, UCLA; member, UCLA Institute of the Environment*
David Simcox, *director, Migration Demographics*
Dick Schneider, *chair, Sierra Club Northern California Regional Sustainability Task Force*
Leon Bouvier (1922-2011), *Ph.D., demographer, Old Dominion University (VA)*
Mark C. Thies, *Ph.D., P.E., professor of chemical engineering, Clemson University*
Marshall Cohen, *Ph.D., professor emeritus of astronomy*, *California Institute of Technology*
Paul Nachman, *Ph.D., physicist*
Scott Briles, *Ph.D., engineer, Los Alamos National Laboratory, University of California*
Steven A. Camarota, *Ph.D., public policy analyst*
William E. Murray, Jr., *Ph.D., physicist*
Michael Mueller, *Ph.D., natural resource economist*

Continued on next page

***** The individuals on this list volunteered to provide advice and guidance to the 2001 Kolankiewicz-Beck sprawl study for NumbersUSA and to have their names listed prominently as Advisors inside the front cover.

The affiliations of the Advisors were listed for identification purposes only, and it was emphasized that the views in the report did not necessarily reflect the views either of the institutions listed alongside them or of all views of the Advisors. Several Advisors helped shape the methodology of the study during the 18 months it lasted, and also assisted with production of interim reports on California and Florida. As the national-level study neared completion, the authors sought the assurance of having many more Advisors with a broad array of expertise to read the results and examine the analysis and methodology. The authors gratefully acknowledged the detailed recommendations, rigorous reviews, and vigorous discussion from and among the Advisors.

Environmental and General Oversight

Albert Bartlett (1923-2013), *Ph.D., professor emeritus of physics, University of Colorado*
Betty B. Davis, *Ph.D.*, *psychologist*
Bill Smith, *Ph.D., dean, College of Global Economics, EarthNet Institute*
Craig Diamond, *adjunct faculty, environmental studies, Florida State University; technical advisor to the Sierra Club carrying capacity campaign*
David Pimentel (1925-2019), *Ph.D., professor of ecology and agricultural sciences, Cornell University*
Diana Hull (1924-2017), *Ph.D., behavioral scientist, retired, Baylor College of Medicine*
Edward G. Di Bella, *adjunct faculty, Grossmont Community College (CA); president, Friends of Los Penasquitos Canyon Preserve*
Garrett Hardin (1915-2003), *Ph.D., professor emeritus of human ecology, University of California, Santa Barbara*
George Wolford, *Ph.D., president, EarthNet Institute*
Herbert Berry, *Ph.D., retired associate professor of computer information systems, Morehead State University (KY)*
James G. McDonald, a*ttorney, civil engineer*
Jeffrey Jacobs, *Ph.D., National Academy of Sciences*
John Bermingham (1923-2020), *former Colorado state senator and Colorado Land Use Commissioner*
John Rohe, *attorney; board, Conservation News Service*
Linda Thom, *retired government budget analyst, Santa Barbara County (CA)*
Michael Hanauer, *member, Vision 2020, growth management project of Lexington (MA)*
Ross McCluney, *Ph.D., principal research scientist, Florida Solar Energy Center, University of Central Florida*
Steve Miller, *former Las Vegas councilman, Clark County (NV) Regional Transportation Commissioner*
Stuart Hurlbert, *Ph.D., professor of biology, San Diego State University*
Terry Paulson, *Mayor Pro-tem, Aspen (CO) City Council*
Tom Reitter, *Livermore (CA) City Council*

Appendix G
Advisors to the 2022 NumbersUSA Study
FROM SEA TO ~~SHINING~~ SPRAWLING SEA: QUANTIFYING THE LOSS OF OPEN SPACE IN AMERICA

Bruce D. Anderson, U.S. Forest Service and Minnesota Department of Natural Resources, Retired

Phil Cafaro, Philosophy Professor and affiliated member of School of Global Environmental Sustainability, Colorado State University; author, *Thoreau's Living Ethics: Walden and the Pursuit of Virtu*e and author/co-editor, *Life on the Brink: Environmentalists Confront Overpopulation*, host, EarthX TV, *The Population Factor*

Trammell S. Crow, Founder of EarthX, the nation's largest annual exposition and forum showcasing/inspiring environmental leadership and innovations across non-profit, corporate and party lines; co-author of *In This Together: How Republicans, Democrats, Capitalists, and Activists Are Uniting to Tackle Climate Change and More*

Herman Daly (1938-2022), Ecological economist and emeritus professor at the University of Maryland, School of Public Policy; author of many books, papers, and articles on steady-state economics

Bob Fireovid, Executive Director, Better (not bigger) Vermont

Dave Foreman (1946-2022), Founder, The Rewilding Institute; author and leading continental-scale conservation advocate

Maria Fotopoulos, Founder, TurboDog Communications and syndicated columnist

Alice Friedemann, Founder, http://www.energyskeptic.com/; author of *Life After Fossil Fuels: A Reality Check on Alternative Energy*

Tom Horton, Author and former journalist, *The Baltimore Sun*; adjunct faculty, Salisbury University

Reed Noss, Chief Science Advisor, Southeastern Grasslands Initiative; past President, Society for Conservation Biology; former editor-in-chief of the journal *Conservation Biology*; elected Fellow, American Association for the Advancement of Science (AAAS); retired professor, University of Central Florida

Tim Palmer, Photographer and award-winning author of 31 books about rivers, conservation and adventure travel, including *Youghiogheny: Appalachian River*; *America's Great Forest Trails*; *America's Great River Journeys*; *Wild and Scenic Rivers: An American Legacy*; *Twilight of the Hemlocks and Beeches*; *Trees and Forests of America*; and *California Wild: Conserving the Spirit and Beauty of Our Land*

David Paxson, Founder and past President, World Population Balance

W.J. Van Ry, Founder, Foundation for Human Conservation

Howie Wolke, Author and nationally recognized wilderness advocate

Appendix H
Sources/Causes of Population Growth in Idaho, Montana, and Wyoming

Sources of Population Growth

Quantifying or estimating the sources or causes of recent population growth in each of the 20 GYE counties in three states (Idaho, Montana, and Wyoming) would involve detailed demographic analysis (number crunching and complex assumptions) beyond and outside the scope of this study. However, we have estimated the sources or causes of recent population growth in each of the three GYE states, which represent a first order approximation (i.e., rough approximate value) of the sources/causes of population growth in the GYE counties per se.

These 20 GYE counties account for 15 percent of the population (544,000 of 3.7 million) and comprise 19 percent of the land area (61,693 of 328,422 square miles) of Idaho, Montana, and Wyoming, the 14th, 10th, and 4th largest states by total (land plus water) area, respectively, in the United States. These are large states with relatively small populations. By comparison, colossal California has about **ten times** the population of all three states combined crammed into about **half their combined land area, ,** meaning that California has a crude population density about 20x that of these three states combined. (And in fact, even this comparison of densities is somewhat misleading, because large swaths of California in its deserts, mountain ranges, and northern forests have very low human population density.)

Idaho

Idaho's population nearly doubled between the 1980 and 2020 U.S. Censuses (**Table H-1**).

Table H-1. Idaho Population by Decennial Census, 1980 to 2020

Year	Population
1980	947,983
1990	1,011,882
2000	1,293,953
2010	1,567,582
2020	1,839,106

From 2010 to 2020, Idaho's population increased by 271,524 and the state had the second fastest growth rate in the nation, behind only Utah.[209] This population growth, reflecting a trend beginning in the late 1980s, was concentrated in southwestern Idaho around the Boise metropolitan area. According to the Census Bureau:

> [Southwestern Idaho] ranks high nationally for levels of in-migration, community amenities and livability, although the increased population continues to drive up real estate prices. The in-migration is also creating stress throughout the state as communities determine how best to pay for growth without pricing out its long-standing residents. Southwestern Idaho contributed to more than half of the decade-long growth in the state and has the largest share of the population among the regions at 46%, an uptick of two points from Census 2010.[210]

In one form of analysis, all of Idaho's population growth can be measured in two sources:

- Natural Increase: births in the state minus deaths in the state.
- Net migration: number of people who moved into the state minus those who moved out of the state.

Figure H-1 shows that natural increase was responsible for 41% of Idaho's population growth from 1990 to 2020.[211] Net migration into Idaho was responsible for the other 59%.

[209] Idaho Department of Labor, "Census 2020 Confirms Idaho Ranks Second Nationally in Population Growth," https://idahoatwork.com/2021/09/03/census-2020-confirms-idaho-ranks-second-nationally-in-population-growth/, accessed September 2, 2023.
[210] Ibid.
[211] U.S. Census Bureau, "State Population Totals and Components of Change: 2010-2019," https://www.census.gov/data/tables/time-series/demo/popest/2010s-state-total.html; "State Population Estimates and Demographic Components of Population Change: April 1, 1990 to July 1, 1999, https://www2.census.gov/programs-surveys/popest/tables/1990-2000/state/totals/st-99-02.txt; "1981 to 1989 Intercensal Estimates of the Resident Population of States, and Year-to-Year Components of Change," accessed September 2, 2023.

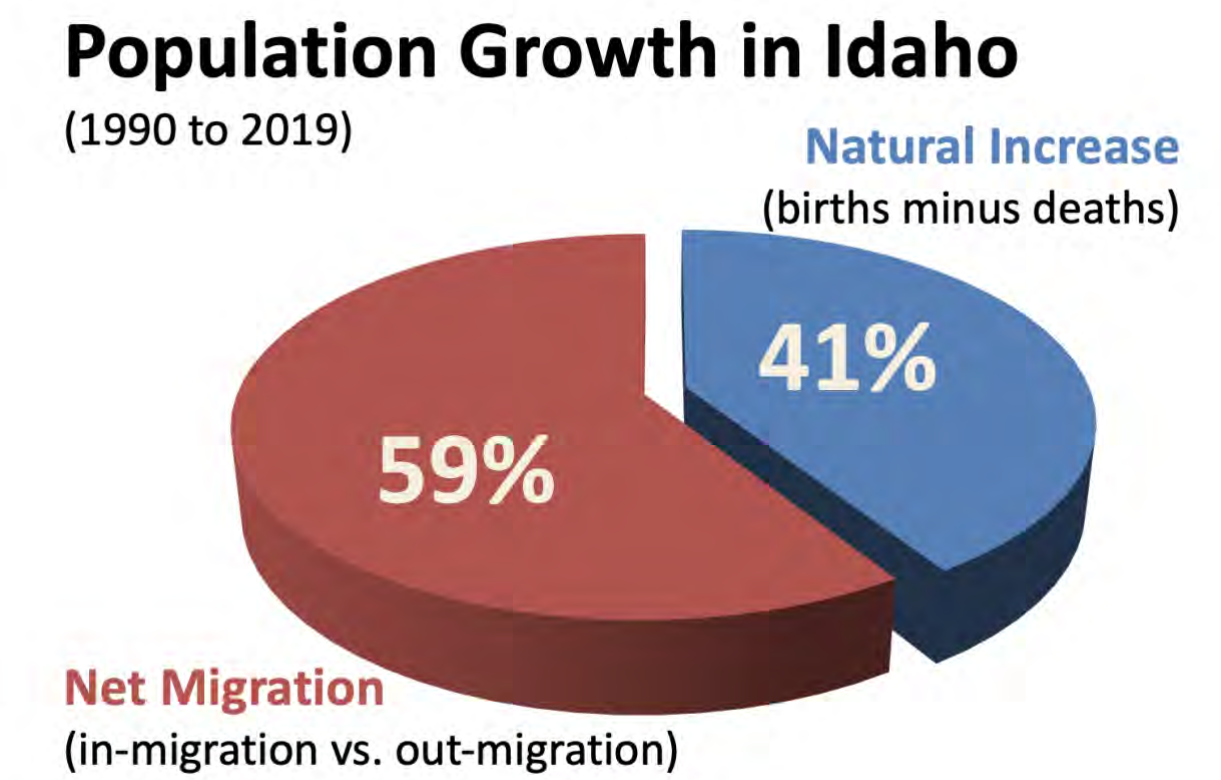


Figure H-1. Percentage of Population Growth in Idaho Due to Natural Increase and Net Migration from 1990 to 2019

The 59% contribution of net migration to Idaho's population growth from 1990 to 2019 includes people who moved to Idaho directly from abroad and people (both U.S.-born and foreign-born) who moved into Idaho from other states.

Another way to measure a state's population growth is to divide all growth between these two sources:

- growth related to international migration (**Table H-2**).
- all other growth that is not related to international migration.

Table H-2. Idaho Foreign-born Population, 1980 to 2020

Year	Population
1980	23,404
1990	28,905
2000	64,080
2010	87,098
2020	106,668

Idaho's foreign-born population grew almost five times larger from 1980 to 2020, though the state's foreign-born population was only 23,404 and just 2.4% of the total population in 1980, making even modest growth seem substantial. While Idaho's foreign-born population has increased at a much more rapid rate than the state's total population, at 5.8% of the state population in 2020, it was still considerably below the 13.7% figure for the United States as a whole.

Figure H-2 shows that 8% of Idaho's population growth from 1990 to 2020 is due to net migration into the state by the foreign-born who moved to Idaho directly from another country. That means 92% of the state's growth in those years came from the combination of natural increase (41%) and net immigration from other states (51%), which includes both those born in the United States and those born abroad who lived in another state before moving to Idaho.

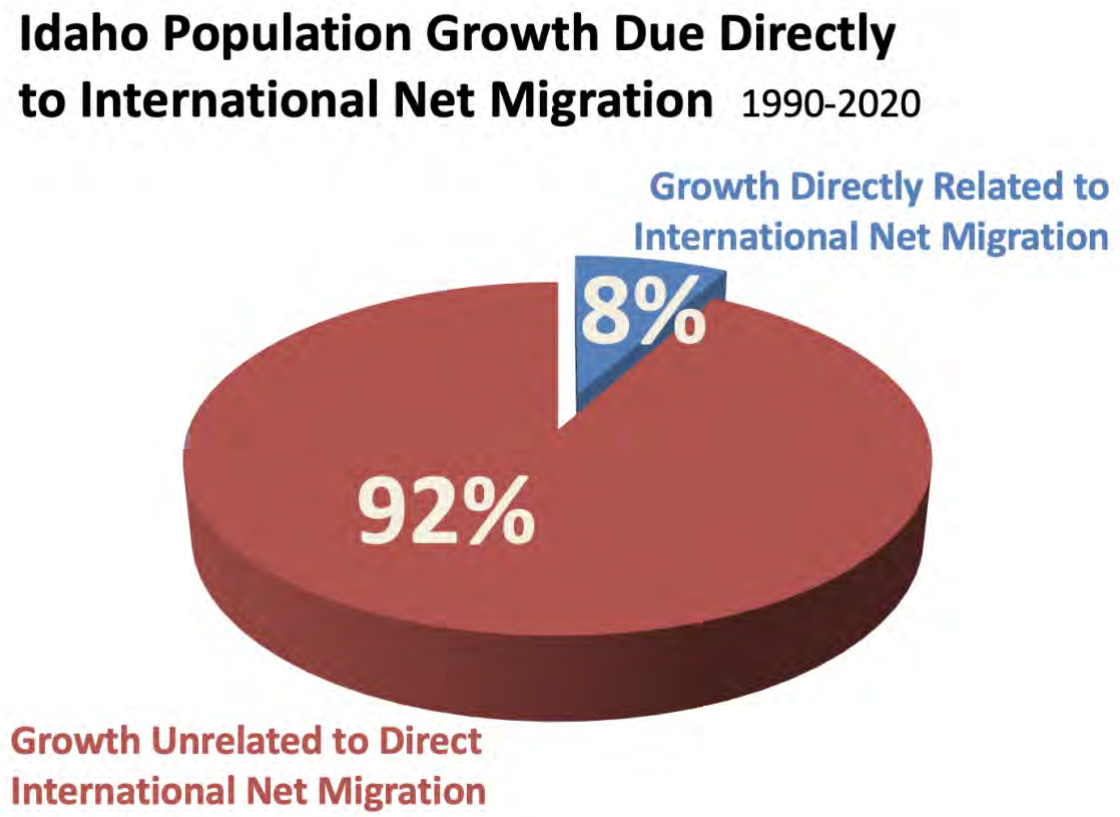


Figure H-2. Percentage of Idaho Population Growth Due Directly to International Net Migration, 1990-2020

International migration, though, has a greater effect on Idaho's population growth beyond immigrants arriving directly in Idaho from other countries. Immigrants who move to Idaho after living in another state also contribute, as they would not have been able to migrate to Idaho if they had not first immigrated to the United States and lived elsewhere. Children who are born to immigrant parents in Idaho, or to immigrant parents living in another state who subsequently move to Idaho, are also contributors and would not have added to Idaho's population if their parents had not immigrated in the first place.

Figure H-3 shows that 18% of Idaho's population growth from 1982 to 2017 (the specific period of our sprawl study) was due to foreign immigration in that period.[212] This is based on

[212] Our estimate of immigration's impact on Idaho's population growth between 1982 and 2017 is based on an analysis of the public use files of the 2017 American Community Survey (ACS) and the 1999 and 2017 Current Population Survey Annual Social and Economic Supplements (CPS ASEC). It is well established that these Census Bureau surveys capture both legal and illegal immigrants. The ACS and CPS identify immigrants (also called the foreign born) and ask what year they came to the United States. We use the 2017 ACS to measure the number of immigrants living in Idaho who entered in 1982 or later. In addition to identifying immigrants and their year of arrival, the CPS asks respondents the birthplace of their parents, allowing us to measure the progeny of post-1982 immigrants in the state.

The 2017 ACS shows 75,000 immigrants living in Idaho who arrived in the country in 1982 or later. This number has been adjusted to exclude half of those who indicated in 2017 that they arrived in the year 1982. This is necessary because the ACS and the population estimate on which overall state population growth is based reflect the population on July 1 of each year. In contrast, the ACS measures immigrant arrivals by calendar year. In addition to immigrants who arrived 1982-2017, we also find based on 2017 CPS ASEC, that there were 38,000 U.S.-born children (under age 18) of post-1982 immigrants in the state. We do this by only counting those with immigrant fathers. We exclude those with only an immigrant mother to avoid double counting. All these children still live with their parents, estimating their number is straightforward.

To estimate the number of U.S.-born adults in 2017 with post-1982 immigrant parents, we use the 1999 CPS ASEC. In 1999, these individuals were still minors and lived with their immigrant parents so we are able to determine the year that the parents arrived. In 1999, 50 percent of second-generation children born 1982 to 1999 with a foreign-born father were the child of a parent who came in 1982 or later. The remainder of U.S.-born second-generation Americans in this age group were born to immigrant parents who arrived prior to 1982. Applying this percentage to the adult children of immigrants 18 to 35 in 2017 means there were 14,000 U.S.-born adult offspring of post-1982 immigrants in Idaho.

Finally, we find that there were 12,000 minor children (<17) with a second-generation parents who are ages 15 to 35 in 2017. We use this age for the second-generation parents as they are old enough to have a child, but young enough to have been born to a post-1982 immigrant. To be clear, these minor children are the grandchildren of immigrants. We again assume that 50 percent of these second-generation parents are the offspring of a post-1982 immigrant giving us an estimated 6,000 U.S.-born grandchildren of post-1982 immigrants in Idaho in 2017.

In total, we estimate there were 133,000 post-1982 immigrants, their children and grandchildren in Idaho in 2017. The state's total population was 965,000 in 1982 and 1,719,745 in 2017. Immigration therefore accounted for almost 18 percent of the 754,745 increase over this time period. (Note the actual percentage is 17.6.)

growth in four groups of residents who would not have been in Idaho if not for foreign migration:

- Foreign-born Idaho residents in 2017 who arrived in the U.S. after 1982 and came directly to Idaho or through another state (75,000).
- Minors (under age 18) in 2017 who were born in the U.S. to post-1982 immigrants (38,000).
- Adults in 2017 who were born in the U.S. to post-1982 immigrants (14,000).
- Minors (under age 18) who are the U.S.-born grandchildren of post-1982 immigrants (6,000).

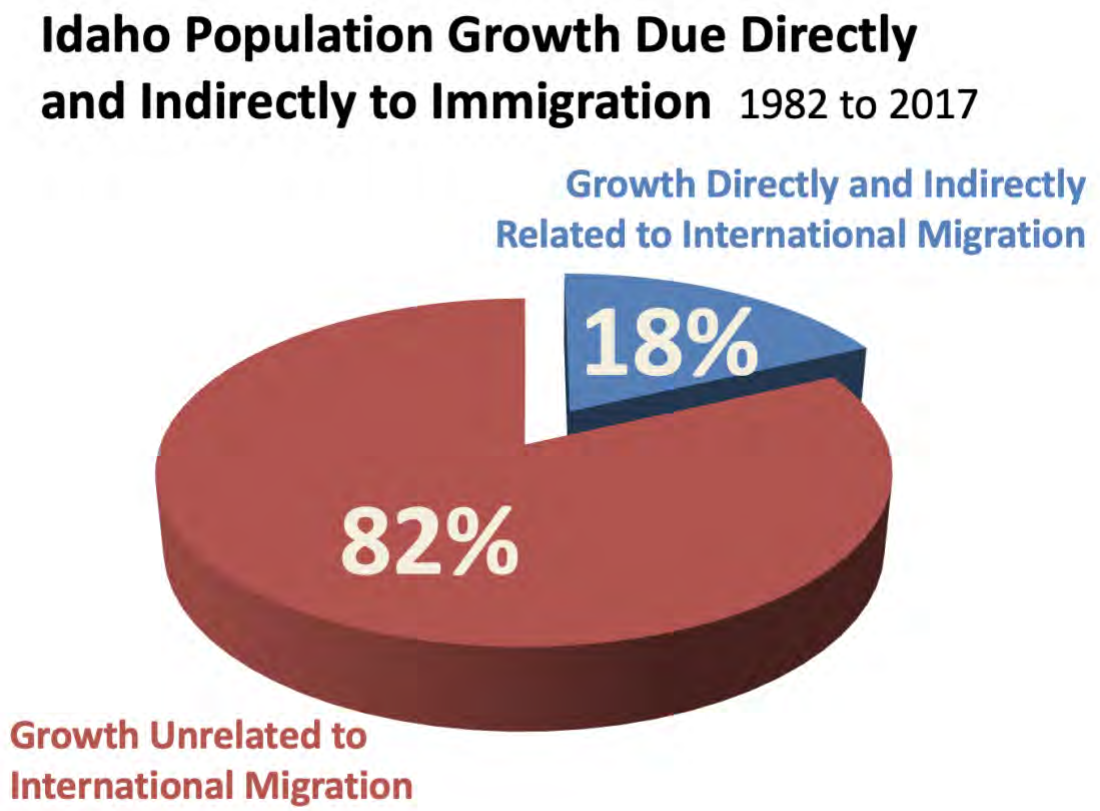


Figure H-3. Percentage of Idaho Population Growth Due Directly and Indirectly to Immigration, 1982 to 2017

In sum, approximately 133,000 residents of Idaho in 2017 would not have moved to the United States or been born in the United States if not for the flow of foreign immigration

between 1982 and 2017. That amounts to about 18% of the state's total population growth. (Footnote #212 explains the methodology, including ways to avoid double-counting.)

The 18% of total Idaho population growth related to immigration (international migration) compares to 56% for the entire United States. Three recent state sprawl studies published by NumbersUSA were for Texas, Colorado, and Arizona. The percentage of population growth related to immigration for those states were 47%, 26%, and 44% respectively. Still, with almost 1/5 of the state's growth due to immigration, it is a factor to consider when discussing growth in Idaho.

In addition, federal immigration policies have indirectly further contributed to Idaho's population growth above the 18% level. A large percentage of U.S.-born migrants to Idaho (not counted in the above categories) have fled other Western states that have experienced many negative quality-of-life developments stemming from their own massive population growth. **Table H-3** shows the states sending the most people to Idaho. All are nearby Western states with high rates of population growth. All but Oregon are also states of high immigration (by numbers or rate of growth).

Table H-3. Top Five Sending States to Idaho (2019)

Rank	State
1.	California
2.	Washington
3.	Oregon
4.	Utah
5.	Arizona

Perhaps the greatest pressure on Idaho's future comes from California having apparently reached some kind of tipping point after a century of massive population expansion to nearly 40 million residents – 20 times the size of Idaho. Since 1982, more than 2 million acres of California have been converted from farmland and natural habitat to developed land while the population boomed.

People fleeing California's extensively documented and heavily publicized socioeconomic and environmental problems – particularly the high cost of housing – are the largest single source of Idaho newcomers.

Idaho, with its population density of 23 residents per square mile, can look awfully alluring to Californians living at a density of 258 residents per square mile and seeking more elbow room and lower housing prices. As high levels of foreign immigration continued into

California in the last decade, nearly 8 million Americans moved from California to other states from 2010 through 2021.[213]

Even a tiny fraction of disgruntled Californians spilling into Idaho can swamp efforts to preserve the state's character and elbow room. Thus, Idaho's future appears inextricably linked to the fate of California, a state that Idaho residents overwhelmingly say they do not want to emulate. Bumper stickers and other signs with slogans such as "Don't Californicate Idaho" attest to their concerns.

Montana

Our estimate of immigration's impact on Montana's population growth between 1982 and 2017 is based on an analysis of the public use files of the 2017 American Community Survey (ACS) and the 1999 and 2017 Current Population Survey Annual Social and Economic Supplements (CPS ASEC). It is well established that these Census Bureau surveys capture both legal and illegal immigrants, though some modest fraction is missed. The ACS and CPS identify immigrants (also called the foreign born) and asks what year they came to the United States. We use the ACS to measure the number of immigrants living in Montana who entered in 1982 or later. In addition to identifying immigrants and their year of arrival, the CPS also asks each respondent the birthplace of their parents, allowing us to measure the progeny of post-1982 immigrants in the state.

The 2017 ACS shows 18,015 immigrants living in Montana who indicated they arrived in the country in 1982 or later. This number has been adjusted to exclude half of those who indicated that they arrived in the year 1982. This is necessary because the ACS and the population estimates on which overall state population growth is based reflect the population on July 1 of each year. However, the ACS measures immigrant arrivals by calendar year. In addition to immigrants who arrived 1982 or later, we also find based on the 2017 CPS ASEC that there were 4,589 U.S.-born children (under age 18) of post-1982 immigrants in the state. (We exclude those with only an immigrant father to avoid double counting.) As these children still live with their parents, estimating their number is straightforward.

To estimate the number of U.S.-born adults in 2017 with post-1982 immigrant parents, we use the 1999 CPS ASEC. In 1999, these individuals were still minors and lived with their immigrant parents, making possible to estimate the year their parents arrived in the United States. In 1999, 50.7 % of second-generation children born 1982 to 1999 with a foreign-born mother were the child of a parent who came in 1982 or later. The remainder of U.S.-born second-generation Americans in this age group were born to immigrant parents who arrived prior to 1982. Applying this percentage to those in the survey who are ages 18 to 35 and report they are the children of an immigrant in 2017 means there were 2,734 U.S.-born adult children of post-1982 immigrants in Montana. It must be remembered that immigration

[213] Ibid.

increased over the entire 1982 to 2017 period, so there are many more recent arrivals in Montana than immigrants who arrived in the earlier part of this time period. This means the vast majority of the offspring of immigrants are under age 18 in 2017 and this is why there are so many more minor children of post-1982 immigrants relative to adult offspring.

Finally, we find that there were 3,520 minor children with second generation parents who are 18 to 35 in 2017. These second generation parents are old enough to have a child, but young enough to have been born to a post-1982 immigrant. We again assume that 50.7 % of these second-generation parents are the offspring of post-1982 immigrants giving us an estimated 1,785 U.S.-born grandchildren.

In total, we estimate there were 27,123 post-1982 immigrants, their children and grandchildren living in Montana in 2017. The state's total population was 801,000 in 1982 and 1.054 million in 2017. Immigration therefore accounted for 10.7 % of the 253,000 increase in the state's population over this time period.

Wyoming

Our estimate of immigration's impact on Wyoming's population growth between 1982 and 2017 is based on an analysis of the public use files of the 2017 American Community Survey (ACS) and the 1999 and 2017 Current Population Survey Annual Social and Economic Supplements (CPS ASEC). It is well established that these Census Bureau surveys capture both legal and illegal immigrants, though some modest fraction is missed. The ACS and CPS identify immigrants (also called the foreign born) and asks what year they came to the United States. We use the ACS to measure the number of immigrants living in Wyoming who entered in 1982 or later. In addition to identifying immigrants and their year of arrival, the CPS also asks each respondent the birthplace of their parents, allowing us to measure the progeny of post-1982 immigrants in the state.

The 2017 ACS shows16,365 immigrants living in Wyoming who indicated they arrived in the country in 1982 or later. This number has been adjusted to exclude half of those who indicated that they arrived in the year 1982. This is necessary because the ACS and the population estimates on which overall state population growth is based reflect the population on July 1 of each year. However, the ACS measures immigrant arrivals by calendar year. In addition to immigrants who arrived 1982 or later, we also find based on the 2017 CPS ASEC that there were 4,390 U.S.-born children (under age 18) of post-1982 immigrants in the state. (We exclude those with only an immigrant father to avoid double counting.) As these children still live with their parents, estimating their number is straightforward.

To estimate the number of U.S.-born adults in 2017 with post-1982 immigrant parents, we use the 1999 CPS ASEC. In 1999, these individuals were still minors and lived with their immigrant parents, making possible to estimate the year their parents arrived in the United

States. In 1999, 50.7 percent of second-generation children born 1982 to 1999 with a foreign-born mother were the child of a parent who came in 1982 or later. The remainder of U.S.-born second-generation Americans in this age group were born to immigrant parents who arrived prior to 1982. Applying this percentage to those in the survey who are ages 18 to 35 and report they are the children of an immigrant in 2017 means there were 2,302 U.S.-born adult children of post-1982 immigrants in Wyoming. It must be remembered that immigration increased over the entire 1982 to 2017 period, so there are many more recent arrivals in Wyoming than immigrants who arrived in the earlier part of this time period. This means the vast majority of the offspring of immigrants are under age 18 in 2017 and this is why there are so many more minor children of post-1982 immigrants relative to adult offspring.

Finally, we find that there were 1,487 minor children with second generation parents who are 18 to 35 in 2017. These second-generation parents are old enough to have a child, but young enough to have been born to a post-1982 immigrant. We again assume that 50.7 percent of these second-generation parents are the offspring of post-1982 immigrants giving us an estimated 754 U.S.-born grandchildren.

In total, we estimate there were 23,810 post-1982 immigrants, their children and grandchildren living in Wyoming in 2017. The state's total population was 502,000 in 1982 and 580,000 in 2017. Immigration therefore accounted for 30.5 percent of the 78,000 increase in the state's population over this time period.

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