National Park Service
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Natural Resource Stewardship and Science

Landscape Dynamics in the Greater Yellowstone Area

Natural Resource Technical Report NPS/GRYN/NRTR–2011/506

ON THE COVER
Residential development near the Bridger Mountains, Montana
Photograph by: Tim Crawford

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is also available electronically from the Greater Yellowstone Network website (http://science.nature.nps.gov/im/units/gryn/index.cfm), the Greater Yellowstone Science Learning Center website (http://greateryellowstonescience.org), and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/)..

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Executive Summary

The resources on parks and public lands are influenced by ecological processes and land use activities on the surrounding landscapes. Consistent data on landscape dynamics (land use and land cover) are necessary for analysis and interpretation of landscape-level trends. This report provides managers in the Greater Yellowstone Area (GYA) with (1) data and methods for ongoing National Park Service (NPS) inventorying and monitoring of landscape dynamics, (2) an analysis of existing publically available landscape dynamics data for areas within and surrounding the GYA, and (3) interpretation of the results in the context of natural resources. This is the first in a series of monitoring reports scheduled every five years by the NPS Inventory and Monitoring Division for the Land Use 'vital sign' in Grand Teton and Yellowstone national parks.

NPScape serves as the primary source for standardized national-level landscape dynamics monitoring in the NPS and for this report. A national-level project of the Inventory and Monitoring Division, NPScape aims to provide relevant landscape-scale information to all possible NPS units with significant natural resources to support natural resource management, planning, and interpretation. NPScape provides a conceptual framework for landscape dynamics monitoring and standardized landscape measures using consistent data and methods across the nation. The products are intended as base-level inventory and monitoring information.

The GYA covers over 92,000 square kilometers in Wyoming, Montana and Idaho. Elevation within the GYA ranges from approximately 1200 m (~ 4000 ft) to 4210 m (~ 13,800 ft). The majority of lands within the GYA are public lands managed by the federal government (67%) with the U.S. Forest Service managing nearly half of the GYA. The National Park Service is the second largest federal land manager and manages approximately 11% of the GYA. Private lands account for roughly 27% of the GYA and a number of private lands are designated as formal conservation lands. Whereas private lands tend to occupy the lower elevations within the GYA, public lands dominate the higher elevations.

Human population in the GYA continues to increase. According to the U.S. Census Bureau, from 1990 to 2010, the population of the 34 counties in and surrounding the Greater Yellowstone Area grew by nearly 35% to over 930,000 residents. The majority of development between 1970 and 2010 was rural residential development (< 6 units/km2). Future projections forecast that development densities will increase with more land moving in to the exurban residential category (7 – 145 units/km2) but that rural residential will continue to dominate the GYA. The overall road density in the GYA is roughly 0.5 km/km2, based on the Tele Atlas road information from circa 2005. The density of major roads (interstates and highways) is 0.04 km/km2 and the weighted road density is 0.6 km/km2. Roadless areas (at least 500 meters from a road) make up large portions of the GYA (~64%). Future land use monitoring reports, scheduled for five year intervals, will provide trend information about road density. Agriculture continues to be a significant land use in the GYA with 2% to 96% of the individual county area in farms in 2007. The majority of land in farms was irrigated and less than one-quarter of the land in farms is cropland.

From 2001 to 2006 there was very little change in the broad-scale natural and converted land cover. In 2006, the majority of land in the GYA was natural land cover (94%), with less than 6%

of the land as agriculture or developed. Forest and scrub/shrub dominated the natural land cover in 2001 and 2006 with approximately 37% forest cover and 35% scrub/shrub cover in the GYA. Most of the forest cover within the GYA is evergreen forest with small areas of deciduous and mixed forests. Forests covered nearly half of the federally owned lands within the GYA in 2006. In contrast, scrub/shrub and (35%) and grasslands (26%) were the predominant land cover on private lands and agriculture accounted for approximately 18% of the land cover on private lands.

While we were able to acquire consistent wildlife habitat data for some species, we encountered numerous datasets for a given species that were inconsistent across state and jurisdictional boundaries, utilized different methodologies and/or had different habitat type definitions. Given our reliance on consistent, publically-available, pre-existing data, the integration of NPScape landscape dynamics data with wildlife information is limited.

Overall, approximately 55,000 km^2 (60% of GYA) within the GYA is mapped as habitat for mule deer. According to models by the Wildlife Conservation Society, approximately 14,000 km^2 are grizzly bear core habitat patches of 50 km^2 or greater and over 8,900 km^2 are core habitat patches of at least 250 km^2 within the GYA. Roughly 90% of the area identified as core grizzly bear habitat is managed by federal land management agencies, predominantly by the U.S. Forest Service. Most of the land cover within grizzly core habitat is forest (~60%) and scrub/shrub (~30%). Forty percent (36,568 km^2) of the GYA is considered wolverine habitat according to habitat estimates from the Wildlife Conservation Society. The majority (> 90%) of wolverine habitat occurs on federally managed lands, predominantly on land managed by the U.S. Forest Service (29,114 km^2) and the National Park Service (4,117 km^2). Just over 3% (1,125 km^2) of wolverine habitat occurs on private lands. According to Wildlife Conservation Society estimates, there are 16,527 km (10,272 miles) of ungulate migratory routes in the GYA (Figure 4.3.8). Elk and mule deer have the longest migratory routes within the GYA.

The landscape dynamics data presented in this report and available through the NPS Greater Yellowstone Inventory and Monitoring Network can be used to help identify, understand, and address landscape-scale management questions related to human use of backcountry and other recreational areas, transportation and infrastructure planning, air travel, night skies, soundscapes and invasive species.

Acknowledgements

We thank National Park Service Greater Yellowstone Network staff members Rob Daley, Cathie Jean, Kristin Legg, and Tom Olliff (now the National Park Service Great Northern Landscape Conservation Cooperative coordinator) for their collaborative efforts in developing this report and an approach to monitoring landscape dynamics. NPScape leads Bill Monahan and John Gross generously shared their ideas and insights and took the time to answer our questions and data requests. Ann Rodman, Yellowstone National Park, and Kathryn Mellander, Grand Teton National Park, provided valuable feedback on the indicators and data sources. We thank Virginia Kelly and the Greater Yellowstone Coordinating Committee for the opportunity to present the approach and findings. Our former colleagues at the Sonoran Institute, John DiBari and Nina Chambers, helped lay the groundwork for this effort. We thank the Wildlife Conservation Society and Brent Brock, Craighead Institute, who shared their wildlife data graciously.

Acronyms

BLM – Bureau of Land Management

BOR – Bureau of Reclamation

GYA – Greater Yellowstone Area

GYCC – Greater Yellowstone Coordinating Committee

GYE – Greater Yellowstone Ecosystem

GRYN – Greater Yellowstone Network

I&M – Inventory and Monitoring

IGBST – Interagency Grizzly Bear Study Team

IUCN - International Union for the Conservation of Nature

LCC – Landscape Conservation Cooperative

NASS – National Agriculture Statistics Service

NLCD – National Land Cover Dataset

NPS – National Park Service

NPScape – NPScape landscape dynamics monitoring program

PAD-US – Protected Areas Database of the United States

SERGoM – Spatially Explicit Regional Growth Model

SI – Sonoran Institute

USCB – U.S. Census Bureau

USDA – U.S. Department of Agriculture

USFS – U.S Forest Service

USGS – U.S. Geological Survey

USFWS – U.S. Fish and Wildlife Service

1 Introduction

1.1 Background

The resources on parks and public lands are influenced by ecological processes and land use activities on the surrounding landscapes. The composition, configuration, and connectivity of land cover types (such as forest, woodland, and scrubland) influence the amount of habitat available for wildlife, how wildlife move across the landscape, and the flow of material and energy (Gross et al. 2009). Both natural and human-caused disturbances can result in large changes in land cover.

Land use is the human use of landscapes, such as agriculture, and residential and other development. Changes in land use outside public land boundaries can have major implications to structural and functional ecosystem properties including fire frequency, species distributions, water quality, air quality, habitat fragmentation, soil erosion, and introduction of exotic species (Gross et al. 2009).

In the early 1990s, National Park Service (NPS) managers surveyed by the U.S. General Accounting Office indicated that activities outside park boundaries were damaging park resources. The threats and stressors identified by the managers fell into four broad categories: urban encroachment, human activities, air pollution, and water quantity and quality issues (U.S. GAO 1994). Since 1940, housing development near national parks, wilderness areas, and national forests increased faster than national average for housing development. Projections suggest that the housing growth increases will likely continue in the near future (Radeloff et al. 2010).

1.2 Goals and Objectives

Trends in housing development described above illustrate the need for managers to consider landscape-level change in management plans and actions. Consistent data on landscape dynamics (land use and land cover) is necessary for analysis and interpretation of landscape-level trends. This report provides managers in the Greater Yellowstone Area (GYA) with (1) data and methods for ongoing National Park Service inventorying and monitoring of landscape dynamics, (2) an analysis of existing publically available landscape dynamics data for areas within and surrounding the GYA, and (3) interpretation of the results in the context of natural resources. The housing, agriculture, and road density measures reported here address long term monitoring objectives identified by national park managers (Jean et al. 2005).

1.3 NPScape

NPScape serves as the primary source for standardized national-level landscape dynamics monitoring in the NPS and for this report (NPS 2010a). A national-level project of the Inventory and Monitoring Division, NPScape aims to provide relevant landscape-scale information to all possible NPS units with significant natural resources to support natural resource management and planning (NPS 1999). Key NPScape objectives are to provide: (1) a coherent conceptual and analytical framework for conducting landscape-scale analyses and evaluations that can inform park-level decisions; (2) credible methods that are well documented, founded on strong science,

and readily repeatable and extensible with local data; (3) informative and useful data and related products at the broad scales not typically available at the park level; and (4) assistance to parks in interpreting results (NPS 2010a).

In order to address questions about conservation opportunities and vulnerabilities, NPScape developed a conceptual framework that integrates measurable attributes of landscapes (Figure 1.1). Three factors are identified in the framework: (1) natural systems; (2) human drivers; and (3) conservation context (NPS 2010a). We modified the conceptual framework by separating agriculture from converted land cover in human drivers category and adding wildlife habitat to the natural systems category.

NPScape provides standardized landscape measures using consistent data and methods across the nation. The products are intended as base-level inventory and monitoring information. The NPScape data sources and products are suited for use in large landscapes (hundreds to thousands of square kilometers) and typically are not appropriate for fine-scale analyses (few kilometers). NPScape also provides detailed methods and tools to enable additional analyses for other spatial extents or using local data. NPScape data, methods, and tools are available online at http://science.nature.nps.gov/im/monitor/npscape/. For this report, we utilized the NPScape source data, methods and tools to analyze landscape dynamics within and near the Greater Yellowstone Area (GYA).

While NPScape provides specific natural system and anthropocentric data as an excellent backdrop against which to compare conservation context elements, it does not contain data for species-specific habitat or animal movement corridors. To demonstrate relationships among the human, natural, and conservation elements of NPScape we identified, analyzed, and interpreted readily available species-specific data sets for grizzly bear, wolverine, mule deer, and ungulate migration.

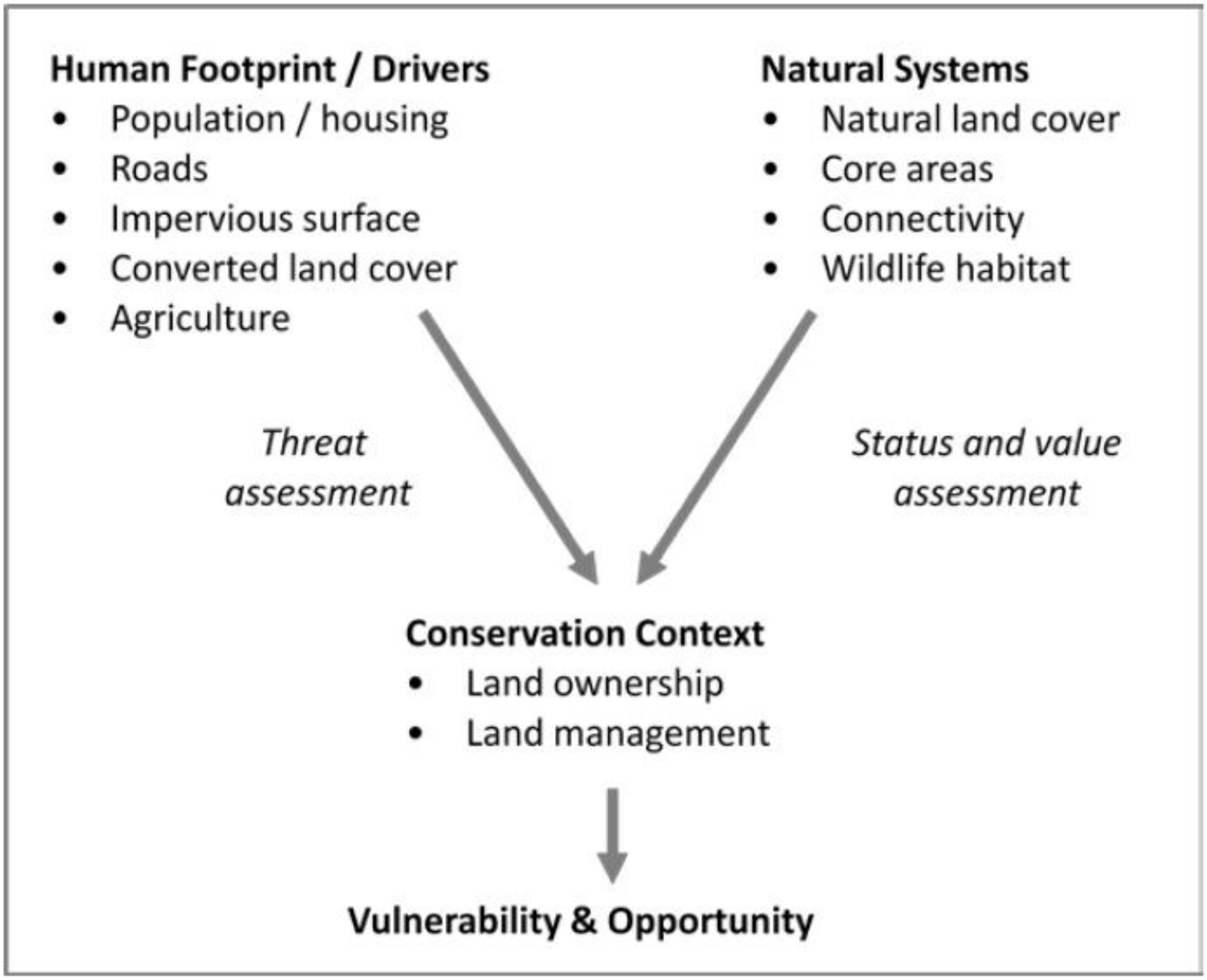


Figure 1.1. Modified NPScape conceptual framework (NPS 2010a).

2 Setting

2.1 Geographic Setting

According to the Greater Yellowstone Coordinating Committee's definition, the Greater Yellowstone Area (GYA) covers over 92,000 square kilometers (km^2) in Wyoming, Montana and Idaho. Elevation within the GYA ranges from approximately 1200 m (~ 4000 ft) to 4210 m (~ 13,800 ft). Whereas private lands tend to occupy the lower elevations within the GYA, public lands dominate the higher elevations within the GYA. The GYA's public lands include national forests, national parks, national wildlife refuges, Bureau of Land management land, and state lands (Hansen et al. 2002). The GYA boundary also overlaps several hundred square kilometers of tribal land.

There are several notable land management partnerships within the GYA (Olliff et al. 2010). The Greater Yellowstone Coordinating Committee (GYCC), formed in 1964, now includes forest supervisors from Beaverhead-Deerlodge, Bridger-Teton, Caribou-Targhee, Custer, Gallatin, and Shoshone national forests, managers from the National Elk Refuge and Red Rock Lakes Refuge, superintendents from Grand Teton and Yellowstone national parks, and a manager from the Bureau of Land Management. The priorities identified by the GYCC include ecosystem health, sustainable operations, landscape integrity, and connection of people to the land. The subcommittees of the GYCC, composed of staff from federal and state agencies and non-governmental organizations, coordinate and carry-out management activities in the GYA. Subcommittees are focused on aquatic and terrestrial invasive species, clean air, fire management, fisheries, hydrology, recreation visitor use, sustainable operations, connecting people to the land, climate change adaptation, and whitebark pine (GYCC 2011).

The Interagency Grizzly Bear Study Team (IGBST) is another example of a prominent partnership within the region (Olliff et al. 2010). The IGBST consists of representatives from the National Park Service, U.S. Forest Service, the U.S. Fish and Wildlife Service, the Bureau of Land Management, and the U.S. Geological Survey; state wildlife agencies from Montana, Idaho, and Wyoming; representatives of local governments from Idaho, Wyoming, and Montana; and representatives from the Shoshone Bannock and Eastern Shoshone tribes. The objectives of the IGBST are to monitor the status and trend of the grizzly bear population within the Greater Yellowstone Ecosystem and to determine patterns of habitat use by bears and the relationship of land management activities to the welfare of the bear population (IGBST 2011).

2.2 Natural Resources

Home to some of America's most well known geysers, glaciers, and wildlife, some consider the GYA the largest intact ecosystem in the continental U.S. (Olliff et al. 2010). Yellowstone, America's first national park is internationally recognized for its geothermal wonders. The park's thermal features include hot springs, steam vents, mudpots, and the world's greatest concentration of geysers (Bryan 2008). Relatively young glaciers still remain on the slopes of the Teton Mountains, which were sculpted by Pleistocene era glaciers. The roughly ten remaining named glaciers in the Teton Range formed during a cold period from approximately 1400-1850 (KellerLynn 2010).

The GYA is notable for its predators, such as black bears, grizzly bears, mountain lions and wolves, and its ungulate species including bison, big horn sheep, mule deer, and pronghorn. The GYA contains the headwaters of the Gallatin, Madison, Yellowstone, Clarks Fork, Wind/Bighorn, Snake and Green Rivers, which provide significant amounts of water to the much larger, Mississippi, Columbia and Colorado Rivers. Many rivers within the GYA support native fish, such as cutthroat trout, and are highly esteemed by anglers. The vegetation communities of the GYA reflect the underlying geology and overarching climate of the area and respond to disturbances such as fire, flood, climate change, insect infestations, and non-native plant invasions. Over time, fire has shaped the GYA landscape and influenced plant community structure and composition and nutrient cycling. Many native plants survive and even flourish following intermittent fires.

2.3 Visitation

The GYA contains some of America's most popular and well-known public lands. The U.S. Forest Service and National Park Service collect information on the annual number of recreational visitors at national forests (NF) and parks, respectively. A recreation visit is the entry of a person into an area for recreational purposes. Bridger-Teton NF and Gallatin NF are the most visited national forests within the GYA. In federal fiscal year 2008, Bridger-Teton National Forest received nearly 2.2 million visits and in 2009, Gallatin NF had just over two million visits. Beaverhead-Deerlodge and Caribou-Targhee NF each had approximately 1.4 million visitors in federal fiscal year 2005. Custer and Shoshone are the least visited national forests in the GYA. Approximately 646,000 visited Shoshone NF in federal fiscal year 2009 and 314,000 people visited Custer NF in federal fiscal year 2008.

Annual recreational visitation statistics for the National Park Service (NPS) cover varying time-periods for Yellowstone National Park (NP; 1904-2010), John D. Rockefeller, Jr. Memorial Parkway (MP; 1972-2010), and Grand Teton NP (1929-2010). Annual visitation to Yellowstone NP was modest in the early 1900s reaching 500,000 annual recreation visitors for the first time in 1940 before declining during World War II (Figure 2.1). Following the war, visitation rapidly increased and in 1948 Yellowstone NP saw over one million recreational visitors. Annual visitation to the park continued to increase, with occasional decreases, topping two million in 1965 and three million in 1992. From 2002-2010, Yellowstone NP averaged just over three million annual recreational visitors. In 1929, the year of the parks founding, Grand Teton NP recorded 51,500 recreational visitors and visitation reached 100,000 by 1935 (Figure 2.1).Similar to Yellowstone NP, Grand Teton NP saw a significant drop in visitation during World War II followed by an increase in visitors following the war. In 1954 and 1963, Grand Teton NP passed the one million and two million recreational visitor marks, respectively. Visitation peaked in 1970 at 3,352,500 and then declined during the 1980s before passing the two million mark again in 1993. From 2002-2010, Grand Teton NP averaged two and a half million recreational visitors per year. Recreational visit use at John D. Rockefeller, Jr. MP has generally been above one million visitors per year since 1973 but tends to be less than at Yellowstone and Grand Teton national parks (Figure 2.1). Since 2002, annual recreation visitors to the memorial parkway averaged 1.1 million (NPS 2011).

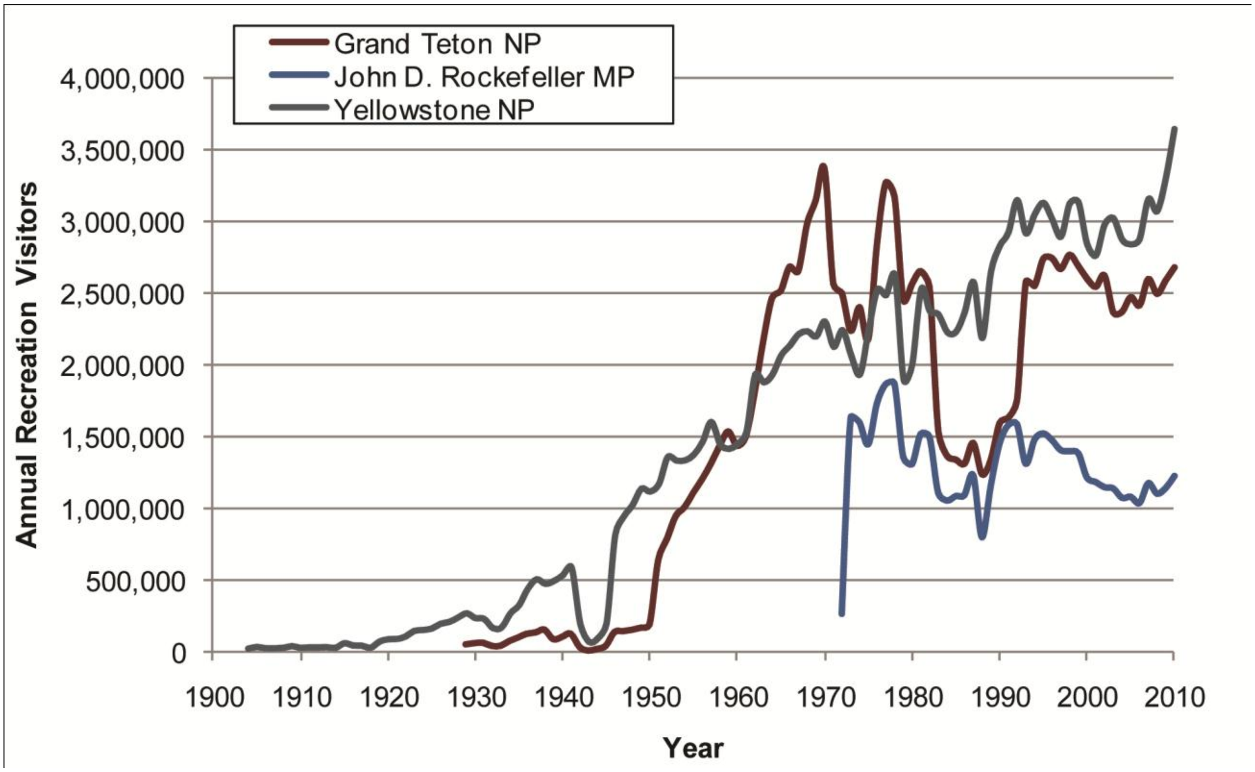


Figure 2.1. Annual recreational visitors at Yellowstone (1904-2010, grey line) and Grand Teton (1929-2010, red line) national parks and John D. Rockefeller, Jr. Memorial Parkway (1972-2010, blue line).

3 Methods and Data Sources

3.1 Landscape Indicators

The landscape dynamics indicators and associated metrics, shown in Table 3.1.1, follow the guidance of the NPScape program and were developed in collaboration with staff from the NPS Greater Yellowstone Network and Yellowstone and Grand Teton national parks. The ecological relevance to the Greater Yellowstone Area (GYA) and data availability (see section 3.3) were also considered. Additional indicators considered but not included in this report were human recreation use, air traffic, night skies, soundscapes, and invasive species. These additional broad-scale topics present an opportunity for future study.

Changes in land cover and land use occur within the context of land management. The land stewardship or conservation status of areas frequently influences potential future changes in land use (Hansen et al. 2005). Land use on surrounding areas affects public lands by altering the effective size of the lands, changing ecological flows, increasing human exposure, and altering critical habitat outside the parks (Hansen and Defries 2007). While these changes can result in positive or negative impacts, they relate to land use intensification (Hansen and Defries 2007) and in many cases relate to land stewardship. Understanding land stewardship and related land uses near public lands provides important context for understanding the status and trends of park resources and is key to coordinated conservation efforts.

Housing density, roads and traffic, population, and agriculture were selected as indicators in the human drivers category (Table 3.1.1). Increases in housing development, and associated roads, can fragment the landscape, decrease the size of the functional ecosystem, reduce connectivity among native habitat patches, isolate species in small patches, increase the contrast in vegetation along park boundaries, and increase the amount of impervious surfaces. Roads directly and indirectly affect wildlife through direct mortality, habitat fragmentation, habitat degradation, and noise (Jackson 2000). Mapping and monitoring roads can be difficult but population size is highly correlated with road traffic (NPS 2009). Therefore, total population is also included as a core indicator of human drivers of landscape change. Agriculture can also have significant ecological impacts on surrounding landscapes such as altering hydrologic regimes and habitat conversion. Due to the importance of agriculture to the region, agricultural land use is a core indicator.

While many of the habitats and vegetation types of concern within the GYA are too spatially restricted or taxonomically detailed, such as whitebark pine, for consistent or reliable mapping in a national effort such as NPScape, land cover by category and impervious surface cover provide important information and both are considered core indicators of natural systems. While basic, the composition, configuration and connectivity of land cover by category (such as forest, woodland, and scrubland) influence wildlife habitat availability and connectivity and the flow of material and energy across the landscape (Gross et al. 2009). Impervious surfaces, such as paved roads and parking lots, prevent precipitation from infiltrating into the ground. Therefore, an increase in impervious surfaces typically results in reduced percolation to the aquifer and flashier streamflow due to faster runoff into streams (Gross et al. 2009). Species specific data, such as

critical habitat and movement corridors, provide an opportunity to relate landscape-scale data to a given species.

Table 3.1.1. Landscape dynamics indicators and metrics in the Greater Yellowstone Area.

Indicator	Metric	Years	Data Source(s)
Conservation Context			
Land management	Area / ownership type Area / land manager	Varies, up to 2010	Protected Area Database of the United States (USGS 2011a)
Conservation status	Area / GAP status Area / IUCN category	Varies, up to 2010	Protected Area Database of the United States (USGS 2011a)
Human Drivers			
Housing density	Housing density	1940 to 2100, by decade	Spatially explicit regional growth model (SERGoM; Theobald 2005; NPS 2010d)
Roads and traffic	Road density Distance from roads Area without roads Average annual daily traffic	Varies, up to 2005	Roads: ESRI and TeleAtlas (ESRI 2008a and 2008b) Traffic: NPS (NPS 2011) and Federal Highway Administration National Transportation Atlas Database (FHWA 2010)
Population	Current total Historic total Projected total	1970 to 2030 by decade	U.S. Census Bureau (USCB 1991, 2001, and 2011), Waisanen and Bliss (2002), Valley County Economic Development, Montana Census and Economic Information Center, Wyoming Dept. of Administration & Information – Economic Analysis Division (NPS 2010c)
Agriculture	Land in farms Land in irrigated farms Land in non-irrigated farms Land in cropland	2002 and 2007	National Agriculture Statistics Service Agricultural Census (NASS 2011)
Natural Systems			
Land cover	Percentage natural vs. converted Area / category Percentage impervious	Circa 2001 and 2006	National Land Cover Dataset (NLCD; MRLC 2011; Fry et al. 2009; Homer et al. 2004; Xian et al. 2009; Vogelmann et al. 2001)
Wildlife habitat and corridors	Habitat by area Migration route length	Varies	Wildlife Conservation Society (WCS), state game and fish agencies

3.2 Areas of Analysis

We utilize two areas of analysis in this report. The Greater Yellowstone Area (GYA), as defined by the Greater Yellowstone Coordinating Committee (GYCC), serves as the primary area of analysis for most of the indicators (Figure 3.2.1). While the NPScape landscape dynamics monitoring program recommends evaluating landscape attributes within 30km of park boundaries to capture ecological processes such as wildland fires and some animal movements (Gross et al. 2009), the ongoing partnerships in the region and the scale of ecological processes suggest that the GYA is a more useful extent for the region. The GYA covers nearly 92,000 square kilometers (km^2) and encompasses the area within 30km of Yellowstone and Grand Teton NPs.

Because population and agriculture data are available by county, the 34 counties considered most influential in terms of regional land use characteristics provide a second area of analysis. In determining the county-level area of analysis, we considered data availability and quality across the area, and jurisdictional relationships.

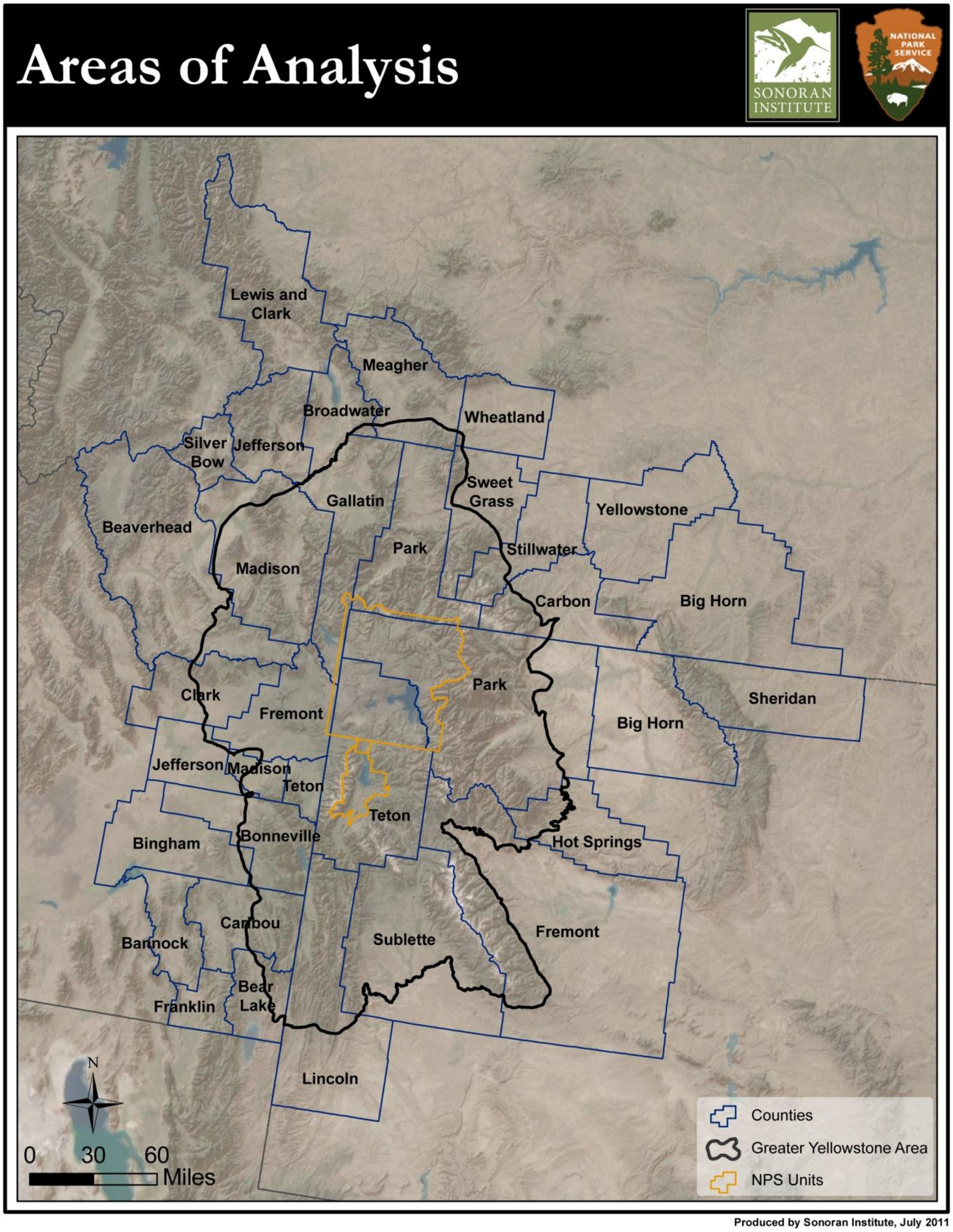


Figure 3.2.1. Areas of analysis for landscape dynamics in the Greater Yellowstone Area.

3.3 Data Sources and Processing

Even with the tools and some data available through NPScape, analyzing landscape dynamics at the GYA-scale required substantial efforts in data acquisition, management, processing, and analysis. In keeping with the direction of the NPScape program, data sources used in this analysis and described below met the following criteria:

- Pre-existing data– No new datasets were generated as we did not conduct field work, classify imagery, or undertake the creation of entirely new data sets.

- Consistency – Data were consistent across broad areas and across jurisdictional boundaries.

- Distribution – Data were publically available and can be redistributed without charge or other undue restriction.

- Documentation – Data included sufficient documentation, including algorithms, procedures, and methodologies.

3.3.1 Land Ownership and Management

The land management and conservation status measures are based on version 1.2 of the Protected Areas Database of the United States (PAD-US v.1.2), a principal data source for land ownership and management that accounts for over 80% of the public land in the U.S. (USGS 2011a, NPS 2010f). The PAD-US is a collaborative effort between the Conservation Biology Institute and the U.S. Geological Survey (USGS) that compiles information on land ownership, stewardship, and management status from a variety of federal, state, and other sources. While PAD-U S attempts to incorporate current information, and presently includes numerous municipal and private conservation areas in the GYA, along with federal and state areas, it does not necessarily include every local conservation area. Another limitation apparent in maps and summary data from the PAD-US is due to variations in feature location and land status attribution from separate contributing federal and state entities and other providers (NPS 2011b). While this report using NPScape relies entirely on PAD-US for land management and conservation measures, future analysis and reporting efforts could consider other data sources such as the multi-partner National Conservation Easement Database (http://www.conservationeasement.us/), which may provide more complete and explicit data for conservation easements in the GYA.

PAD-US v.1.2 improves on v.1.1 with ‘complete updates’ to Idaho, Montana, and Wyoming from the USFS, BLM, and The Nature Conservancy. (USGS 2011b). NPS parcel data and GAP status codes for NPS lands were reviewed for PAD-US v.1.2, along with updates to wilderness areas following the Omnibus Public Lands Act of 2009, updates from the BLM National Landscape Conservation System (NLCS) (not including NLCS National Trails and Wild and Scenic Rivers), and updates to Department of Defense lands (USGS 2011b).

NPS units from PAD-US v.1.2 that appear outdated or show incorrect attributes in this report should be brought to the attention of the NPScape project leaders and/or staff of the Greater Yellowstone Inventory and Monitoring Network in order to update future versions of the protected areas database.

Mapping and reporting are based on the status codes described below. The GAP Status Code in the PAD-US is an encouraged (but not required) measure of management intent to conserve biodiversity. While GAP focuses on promoting biodiversity conservation and the long-term survival of species in the United States, the International Union for the Conservation of Nature (IUCN) helps societies worldwide to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable. Accordingly, the GAP status codes are more complete than IUCN status codes for the GYA, and future additions to the PAD-US should help fill in missing information. Typically national parks are classified as GAP status 1 while wilderness areas and wildlife refuges are classified as GAP status 2. Both codes represent protected areas as defined by NPScape. The GAP status assignment applies to the entirety of formally designated units.

> **GAP Status 1:** An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management.
>
> **GAP Status 2:** An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance.
>
> **GAP Status 3:** An area having permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low-intensity type (e.g., logging) or localized intense type (e.g., mining). It also confers protection to federally listed endangered and threatened species throughout the area.
>
> **GAP Status 4:** There are no known public or private institutional mandates or legally recognized easements or deed restrictions held by the managing entity to prevent conversion of natural habitat types to anthropogenic habitat types. The area generally allows conversion to unnatural land cover throughout.
>
> **- -**
>
> **IUCN Category Ia:** Strict Nature Reserves are strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure preservation of the conservation values. Such protected areas can serve as indispensible reference areas for scientific research and monitoring.
>
> **IUCN Category Ib:** Wilderness Areas are protected areas that are usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.

IUCN Category II: National Park protected areas are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities.

IUCN Category III: Natural Monument or Feature protected areas are set aside to protect a specific natural monument, which can be a land form, sea mount, submarine caverns, geological feature such as caves or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value.

IUCN Category IV: Habitat/species management protected areas aim to protect particular species or habitats and management reflects this priority. Many category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of this category.

IUCN Category V: Protected landscape/seascape protected areas occur where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value.

IUCN Category VI: Protected area with sustainable use of natural resources are generally large, with much of the area in a more-or-less natural condition and where a proportion is under sustainable natural resource management and where such exploitation is seen as one of the main aims of the area.

We acquired the ArcGIS version 9.3 Geodatabase of the PAD-US v.1.2 dataset from USGS (http://gapanalysis.usgs.gov/data/padus-data/padus-data-download/) and utilized the ArcGIS Toolbox provided in Phase 2 release of the NPScape data and tools to estimate land management and conservation status for the GYA. The ArcGIS tools clip the PAD-US data to the area of analysis and calculate the total area and percent of the area of analysis by land ownership (federal, non-federal public [state, local], tribal, private, and water), by land manager, and by conservation status (GAP status and IUCN category). NPS (2011b) contains additional detail on the NPScape tools. The PAD-US v.1.2 dataset did not cover the complete spatial extent of the GYA because many private lands were not included in the database. To generate a spatially continuous ownership/management dataset for the GYA, the processed PAD-US v.1.2 dataset was unioned (100m xy tolerance) with the GYA boundary. Lands not included in PAD-US v1.2 were assumed to be private and were attributed as such.

3.3.2 Population

Since 1790, the decennial census has been conducted in years ending in zero, as required by the U.S. Constitution. The U.S. Census Bureau has overseen the decennial census since the early 1900s. The U.S. Census Bureau provides information at a variety of spatial scales: block, block-groups, tracts, counties and states (in ascending order with respect to population totals). Within an urban area, census blocks are roughly equivalent to a city block. Census block groups are aggregations of census blocks. The larger census tracts, which typically contain 2500 to 8000

people, are designed to be homogenous with respect to economic status and other population characteristics and do not cross county boundaries. Census data can be freely downloaded from the Census Bureau's American Factfinder website (http://factfinder.census.gov and http://factfinder2.census.gov).

Waisanen and Bliss (2002) summarized population and agriculture for counties in the coterminous U.S. from 1790-1997. They addressed county boundary changes and attributed census data to the appropriate spatial region. Therefore, we utilize Waisanen and Bliss (2002) as the intermediate source for population data from 1860-1980. While the data is available online (http://landcover.usgs.gov/cropland/), we acquired the historic population data from the NPScape program. The decennial census served as the source data for the 1990, 2000 and 2010 population estimates (USCB 1991, 2001, and 2011). We acquired data at the county and census block group level. The NPScape program acquired and compiled population estimates for the GYA from the Valley County (Idaho) Economic Development Office, Montana Census and Economic Information Center, and Wyoming Department of Administration and Information – Economic Analysis Division (NPS 2010c). For this analysis, we acquired the processed population projection dataset from the NPScape program.

To generate the population measures, we utilized the NPScape python tools (Phase I release). Population change evaluates the total number and percent change in population between two time periods. Population density in 1990, 2000, and 2010 for each census block group was calculated by dividing the number of people by the area of the census block group (in square kilometers). Excluding areas protected from human settlement would result in high population densities (Svancara et al. 2009a).

3.3.3 Housing Density

The Spatially Explicit Regional Growth Model (SERGoM version 3) served as the source data for the housing density measure (Theobald 2005; NPS 2010d). Dave Theobald graciously allowed NPScape to utilize and share the outputs of SERGoM for landscape dynamics monitoring. SERGoM v3 utilized U.S. Census Bureau data from 2005 or earlier to estimate the number of housing units per block. SERGoM also considered land ownership, land management, and major roads (interstates, state highways, county roads) to allocate housing units within a block. Population estimates from Woods & Poole Economics, Inc. were combined with a supply-demand-allocation approach that assumed growth patterns would be similar to those from the previous decade (Svancara et al. 2009a). Therefore, the housing density projections made by SERGoM may not reflect actual growth if the underlying forecasts change.

While local housing density and tenure data are available for portions of the GYA (e.g., Gude et. al 2006; Gosnell et al. 2006; Gude et. al 2007), most of the efforts were one-time projects and/or did not cover the entire GYA. Since SERGoM has an established relationship with NPScape, and NPS staff anticipate receiving updates to SERGoM in the future (B. Monahan pers. comm.), we utilized SERGoM in this analysis.

NPScape acquired the results of SERGoM version 3 from Dave Theobald and resampled the data to a 100m cell size. In the SERGoM data, each cell with no development restrictions ("developable land") was assigned to housing density class (housing units per km^2). Note that SERGoM does not consider the potential for lands that are currently protected from development

to be developed in the future. However, SERGoM does allow development on Native American lands. SERGoM utilizes non-uniform ranges for the housing density class to better capture low-density rural housing developments.

While we acquired the SERGoM data from the NPScape program for 1940 through 2100, we focused our analysis on the more relevant time period between 1970 and 2030. We utilized the python scripts provided by NPScape to analyze housing density estimates and projections within the GYA. In summary, the python scripts extract the area of interest, populate attributes such as total area and percent of area of analysis, generate summary statistics tables, and import NPScape metadata (NPS 2010d). NPS (2010d) contains additional detail on the data processing steps.

Theobald (2005) defined four classes of development: rural (0-0.0618 units/hectare [ha]), exurban (0.0618-1.47 units/ha), suburban (1.47-10.0 units/ha), and urban (> 10.0 units/ha). We reclassified the SERGoM data in Microsoft Excel to follow Theobald's (2005) development classes: rural (0-6 units/km^2), exurban (7-145 units/km^2), suburban (146-1,234 units/km^2), and urban (> 1,234 units/km^2) and calculated the percent of the area of analysis and percent "developable land" for each time period.

3.3.4 Roads and Traffic

The roads indicator utilizes road data derived from the ESRI StreetMap North America dataset, distributed with ArcGIS 9.3. The dataset includes the Tele Atlas North America base data and the Tele Atlas streets for North America (Svancara et al. 2009b; ESRI 2008a and 2008b). The roads data acquired from the NPScape program was updated in 2005 (NPS 2010e).

We utilized the python scripts provided by NPScape program to estimate road density, distance from roads, and areas without roads for the GYA. The scripts calculate road density (km/km^2) within each grid cell for all roads, major roads, and weighted roads. Major roads include interstates and highways. In weighted road calculations, interstate lengths are multiplied by five and highway lengths are multiplied by three to estimate traffic volume by major road type. To calculate distance from roads, the python scripts utilize the road vectors to generate Euclidean distance rasters with a 100m cell size. The python script also produces a polygon shapefile of roadless areas that are at least 500m from the nearest road. In order to reduce the artifacts in the calculations, the python scripts buffer the area of analysis by 10km. In summary, the python scripts clip the road input data to the buffered area of analysis, calculate road segment lengths, generate statistics summary tables, and generate the road density and distance from roads rasters. NPS (2010e) contains additional detail on the data processing steps.

The 2005 annual average daily traffic counts for non-NPS roads were acquired from the Federal Highway Administration National Transportation Atlas Database (FHWA 2010). We eliminated points that had a low confidence rating for spatial accuracy or that had annual average daily traffic counts of zero. Following the data processing, seventeen points within the GYA remained. At each point, the appropriate state department of transportation reported annual average daily traffic counts to the Federal Highway Administration for inclusion in the National Transportation Atlas.

For NPS roads, we acquired monthly traffic counts from 1991 to 2011 from the NPS Public Use Statistics Office (NPS 2011) for Yellowstone and Grand Teton NPs and John D. Rockefeller, Jr. MP. The approximate location of each traffic counter was generated in ArcMap based on aerial imagery and park data. For each traffic counter, the 2005 annual average daily traffic was determined for comparison with the National Transportation Atlas data.

3.3.5 Agriculture

The U.S. Department of Agriculture (USDA), National Agriculture Statistics Service (NASS) conducts a Census of Agriculture every five years. The agricultural census data was the responsibility of the U.S. Census Bureau until 1997. From 1840, the date of the first agriculture census, through 1950 the agriculture census was a part of the decennial census. The agriculture census was taken in years ending in 4 and 9 from 1954 to 1974 and then in 1978 and 1982. Thereafter, the agriculture census was conducted in years ending in 2 and 7. The Census of Agriculture provides a comprehensive, detailed, and uniform data on U.S. farms and ranches at the state and county-level. Farm and rangeland are collectively referred to as farms in the Census of Agriculture and throughout this report. Data are not published if it reveals information on a single farm or ranch. In addition, if a farm spans more than one county it is counted in both counties. Therefore, it is possible to report more land in farms than the total amount of land within a county. In the Census of Agriculture, a farm is "any place from which $1,000 or more or agricultural products were produced and sold, or normally would have been sold, during the census year" (NASS 2011).

We acquired the NASS Desktop Data Query Tool with county-level data from the 2002 and 2007 Censuses of Agriculture (NASS 2011). We exported data on land in farms, cropland, pastureland, and irrigation from the Data Query Tool. We utilized Microsoft Excel to convert the data from acres to square kilometers and to generate summary tables.

3.3.6 Land cover and impervious surfaces

For the land cover and impervious surface measures we utilized data from version 2 of the circa 2001 National Land Cover Dataset (NLCD) (updated in 2011; Vogelmann et al. 2001; Homer et al. 2004), the circa 2006 NLCD (Xian et al. 2009), and the NLCD 2001/2006 Land Cover Change product (MRLC 2011), which we acquired from the Multi-Resolution Land Characteristics Consortium (MRLC 2011). The 2006 NLCD was released in February 2011 and the 2011 NLCD is expected to be released in 2013. As part of the 2006 NLCD data release, MRLC revised and reissued the 2001 NLCD products (2001 NLCD Version 2.0) to allow comparison between the 2001 and 2006 products. The majority of the updates to the 2001 NLCD occurred in coastal areas (MRLC 2011). The NLCD is available as a seamless dataset with 30m resolution (900m^2) and has a 2 acre minimum mapping unit. While the 2001 NLCD retained as much compatibility with the 1992 NLCD as possible, differences in the classifications and mapping methodologies prevent the direct comparison of the 1992 and 2001 NLCDs. The USGS NLCD team devised a multistep methodology for comparing the 1992 and 2001 NLCDs, which resulted in the 1992/2001 Land Cover Change Retrofit Product (MRLC 2001). Due to the different methodologies used over time, we do not include data from the 1992/2001 Land Cover Change Retrofit Product (Fry et al. 2009) or the 1992 NLCD. In general, the NPScape python scripts clipped the NLCD data to the GYA area of analysis and reclassified the data into thematic

categories (Appendix A). For each thematic category, the area by class and percent total area are calculated. NPS (2010b) contains additional detail on the data processing steps.

While other local efforts utilize remotely-sensed data to classify land cover and land use in the vicinity of the GYA, the NLCD is the only consistent, full-coverage dataset known to be available on a periodic future basis. The NLCD is also advantageous for monitoring land use because it is free and publically available. As a nation-wide effort, the NLCD is not expected to completely represent fine-scale land cover within the GYA because NLCD analyses and products are subject to overall study objectives and assumptions, characteristics of thematic definitions, spatial resolution, and applied scales. These include the assumption of homogenous categories based on the dominant vegetation that do not account for patch/stand characteristics, an exaggeration of the definitiveness of boundaries between classes that can mask transition areas and gradients, inconsistencies across mapping extents or zones (NPS 2010b). In addition, all proportional calculations depend on the size of the sampling unit.

The 2001 and 2006 NLCDs contain 21 land cover classes (modified from Anderson et al. 1976) known as Anderson Level II classes, which are aggregated into 8 Anderson Level I classes (Appendix A). To evaluate the amount of natural land cover extent within the GYA, we followed NPScape guidance and analyzed land cover at both the Anderson Level I and II classifications. We also evaluated broad land cover categories (natural versus converted) (Appendix A; NPS 2010b). We reclassified the 2001 to 2006 change product according to MRLC guidance (Appendix B; MRLC 2011) to evaluate broad changes in natural versus converted lands from 2001-2006. The NLCD impervious surface classes were reclassified according to NPScape guidance (Appendix C; NPS 2010b). To calculate the total amount of impervious surfaces within the watershed, we multiplied the mid-point of each impervious category by the area within each category, summed the results, and divided by the total area of analysis.

3.3.7 Wildlife habitat and corridors

We attempted to identify the best publically-available species-specific data sets for each of the six ungulates (bighorn sheep, bison, elk, moose, mountain goats, mule deer, pronghorn, and white-tailed deer) and seven large predators (black bears, Canadian lynx, coyotes, grizzly bears, mountain lions, wolverines, and wolves) found in the GYA. However, we were only able to compile consistent data on habitat ranges for grizzly bear, wolverine, and mule deer, and ungulate migration. We located habitat data for elk and pronghorn but the data was not consistent across Idaho, Wyoming, and Montana. Appendix D contains information on additional wildlife data that we located and processed but that is not included in the main body of this report. Below we provide a background on the data and methodology used to identify species-specific habitat and movement corridors for these species.

In processing these data, all attempts were made to retain the resolution and characterization of the original data, rather than homogenize habitat classifications across state boundaries. This is particularly evident in data layers that originated in state wildlife agencies, and perfect matches for each habitat type were not available across state boundaries.

With the exception of the migratory corridors, which are linear features, wildlife data in the GYA was extracted primarily through the "Zonal – Tabulate" function in ArcGIS 10, which

overlays two GIS layers and calculates the area of overlay between specified attribute fields in each layer.

Mule Deer

Mule deer data are accessible from the Mule Deer Working Group housed at the Utah State University Remote Sensing and GIS Laboratory (www.gis.usu.edu/current_proj/muledeer.html). The project employed an expert opinion approach to map all mule and black-tailed deer habitat in North America and Mexico. Regional representatives worked through state-based workshops to identify and delineate habitat on a state by state basis. Habitat areas were delineated on 1:250,000 sheet maps with a minimum mapping unit of approximately 6 square miles. Six categories of mule deer habitat were delineated, with 18 factors limiting or otherwise affecting the habitat (public land habitat availability, increased road densities, riparian impacts, timber harvest impacts, agricultural crop depredation, limited private land access, artificial feeding, habitat conversion, social carrying capacity exceeded, late seral stages needed, high density recreation, water availability, transport/water conveyance corridors, mineral extraction/exploration, competition with other wild ungulates and special situations). These data were digitized and compiled into a GIS database (Remote Sensing/GIS Laboratory, Utah State University). We considered three categories of mule deer habitat:

Winter Range: The part of the overall range where 90 percent of the individuals are located during the average of five winters out of ten from the first heavy snowfall to spring green-up, or during a site-specific period of winter. A subset of this definition would include a "severe winter range" definition to include areas within the winter range where 90% of the individuals are located when annual snow pack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten.

Winter Concentration: Portions of the winter range where densities are at least 200% greater than the surrounding winter range density during the same period used to define winter range in the average of five winters out of ten.

Year-round Population: Areas that provide year-round range for a population of mule deer. The resident mule deer population use all of the area all year; it cannot be subdivided into seasonal ranges although it may be included within the overall range of the larger population.

Grizzly Bear

Walker and Craighead (1997) modeled grizzly bear core habitat as part of a wildlife movement corridors models. Their corridor analysis was based on four assumptions: 1) good corridors are comprised primarily of preferred habitat types; 2) humans pose problems for successful transit; 3) current human developments are permanent; and 4) the least cost offers an animal the greatest probability of success (Walker and Craighead 1997). The potential corridor routes were modeled based on three inputs: 1) habitat quality (based on state Gap Analyses); 2) length of forest and shrub/grassland interface; and 3) road density. During the modeling process, core areas were generally allocated on public lands (Walker and Craighead 1997).

Wolverine

The Wildlife Conservation Society (WCS) estimated the distribution of primary wolverine habitat in the conterminous Rocky Mountains with logistic regression of 1,284 telemetry

locations of 16 wolverines captured in the GYA, habitat variables appropriate for broad-scale prediction, and validation with three independent datasets. WCS also estimated the number of potential adult female territories within habitat complexes, and identified federal administrators of primary habitat. Cross correlation and testing with independent datasets indicated that the combined sex and season model, which included latitude-adjusted elevation, terrain ruggedness index, conifer cover, snow depth, forest edge, and road density, is robust to extrapolation and can provide a foundation for collaborative, landscape-level planning in the Rocky Mountain states (Brock and Inman 2007). Core habitat is defined as specific areas of habitat essential for the long-term survival of a species.

Ungulate Migratory Routes

The Wildlife Conservation Society (WCS) compiled data on migration route locations for Wyoming, Montana, and Idaho to generate a GIS dataset on large mammal migration routes for five ungulate species (elk, mule deer, bighorn sheep, moose, and pronghorn) in the Greater Yellowstone Ecosystem (GYE). Each route is assigned a confidence ranking, a threat score and mean threat value based on the likelihood of adverse impacts from human land use along the length of the route (Lyons 2006). The purpose of this data set is to provide spatial data on the location of ungulate migration routes within the GYE, as well as a comparative estimate of the degree to which those routes are threatened by human activities.

Mean threat value, as derived from the summed threat surface was averaged over the length of each individual migration route using the combined threat layer and the zonal statistics tool in ArcGIS 9.0. The mean threat levels were converted from values between 0 and 1 to an integer threat score for each line by dividing by the highest mean threat score for any route (0.657) and multiplying by 100. The resulting threat scores range from 0 to 100, with higher values corresponding to higher threat levels. These scores can be interpreted as the overall degree to which a route is impacted by deleterious human uses and thus is apt to be impaired. Scores and mean threat levels were appended to the combined data set of GYE migration routes using the unique state IDs. (WCS 2011a)

4 Results and Discussion

4.1 Conservation Context

4.1.1 Land ownership and management

The majority of lands within the Greater Yellowstone Area (GYA) are public lands managed by the federal government (67%; Table 4.1.1), based on the PAD-US version 1.2. The U.S. Forest Service (USFS) manages nearly half of the GYA, which includes all or portions of the Beaverhead-Deerlodge National Forest, Bridger-Teton National Forest, Caribou-Targhee National Forest, Custer National Forest, Gallatin National Forest, and Shoshone National Forest. The National Park Service (NPS), with Yellowstone and Grand Teton national parks and John D. Rockefeller, Jr. Memorial Parkway, is the second largest federal land manager (11% of GYA). The Bureau of Land Management (BLM) manages approximately 7% of the GYA while the U.S. Fish and Wildlife Service (USFWS) and Bureau of Reclamation (BOR) manage less than 1% of the area. Private lands account for roughly 27% of the GYA and a number of private lands are designated as formal conservation lands.

Table 4.1.1. Land Management in the Greater Yellowstone Area (GYA).

Manager	km^2	% GYA
Federal	**61199**	**66.7%**
Bureau of Land Management	6442	7.0%
Bureau of Reclamation	132	0.1%
Fish and Wildlife Service	428	0.5%
Forest Service	43823	47.8%
National Park Service	10116	11.0%
Natural Resources Conservation Service	125	0.1%
Other Federal Land	133	0.1%
Native American	**1676**	**1.8%**
Wind River Indian Reservation	1676	1.8%
State	**3888**	**4.2%**
State Fish and Wildlife	560	0.6%
State Park & Recreation	109	0.1%
State Land Board	2160	2.4%
State Department of Land	1023	1.1%
State Department of Natural Resources	35	0.04%
Local Government	**18**	**0.02%**
City Land	18	0.02%

Table 4.1.1. Land Management in the Greater Yellowstone Area (GYA).

Manager	km^2	% GYA
Non-Governmental Organization	**31**	**0.03%**
The Nature Conservancy	31	0.03%
Local Land Trust	< 1	0.001%
Private	**24404**	**26.6%**
Private Non-profit	46	0.05%
Private Conservation	2182	2.4%
Private	22176	24.2%
Unknown	**494**	**0.5%**
Unknown	494	0.5%

4.1.2 Conservation status

According to the PAD-US version 1.2, 43% of the lands within the GYA have permanent protection from conversion of natural land cover for the majority of the area, but are subject to extractive uses of either a broad, low-intensity type (e.g., logging, OHV recreation) or localized intense type (e.g., mining). These lands are classified as GAP Status 3 that confer protection to federally listed endangered and threatened species throughout the classified areas. About 21% of GYA lands are permanently protected from conversion of natural land cover. These GAP Status 1 areas have a mandated management plan in effect to maintain a natural state within which disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management. Gap Status 2 lands account for some 10% of the GYA and are permanently protected from conversion of natural land cover with a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance. Of the remaining areas in the GYA, approximately 24% do not have a GAP Status assigned, and 2% have no known public or private institutional mandates or legally recognized easements or deed restrictions held by the managing entity to prevent conversion of natural habitat types to anthropogenic habitat types. These GAP Status 4 areas generally allow conversion to unnatural land cover throughout or management intent is unknown.

The majority of lands in the GYA were not assigned to an IUCN category (Figure 4.1.1). Of the lands that were assigned an IUCN category, most were assigned to Ib (18%; wilderness areas) and II (11%; national park). USFS wilderness study areas, BLM research natural areas, and The Nature Conservancy preserves were assigned to the IUCN category Ia (strict nature reserve) but accounted for less than 1% of the lands within the GYA. No lands were assigned to IUCN categories III (natural monument or feature) or VI (generally large sustainable use of natural resources).

Different interpretations by managing units of the criteria for assigning GAP Status Codes may explain why some designated wilderness areas in the GYA are assigned GAP Status Code 1

while others are assigned GAP Status Code 2 in figure 4.1.1. For example, GAP Status Code 2 could be submitted for a designated wilderness area if the person judges that the area "allows low anthropogenic disturbance, renewable resource use, or high levels of human visitation on more than 5% of the land unit" (USGS 2011c).

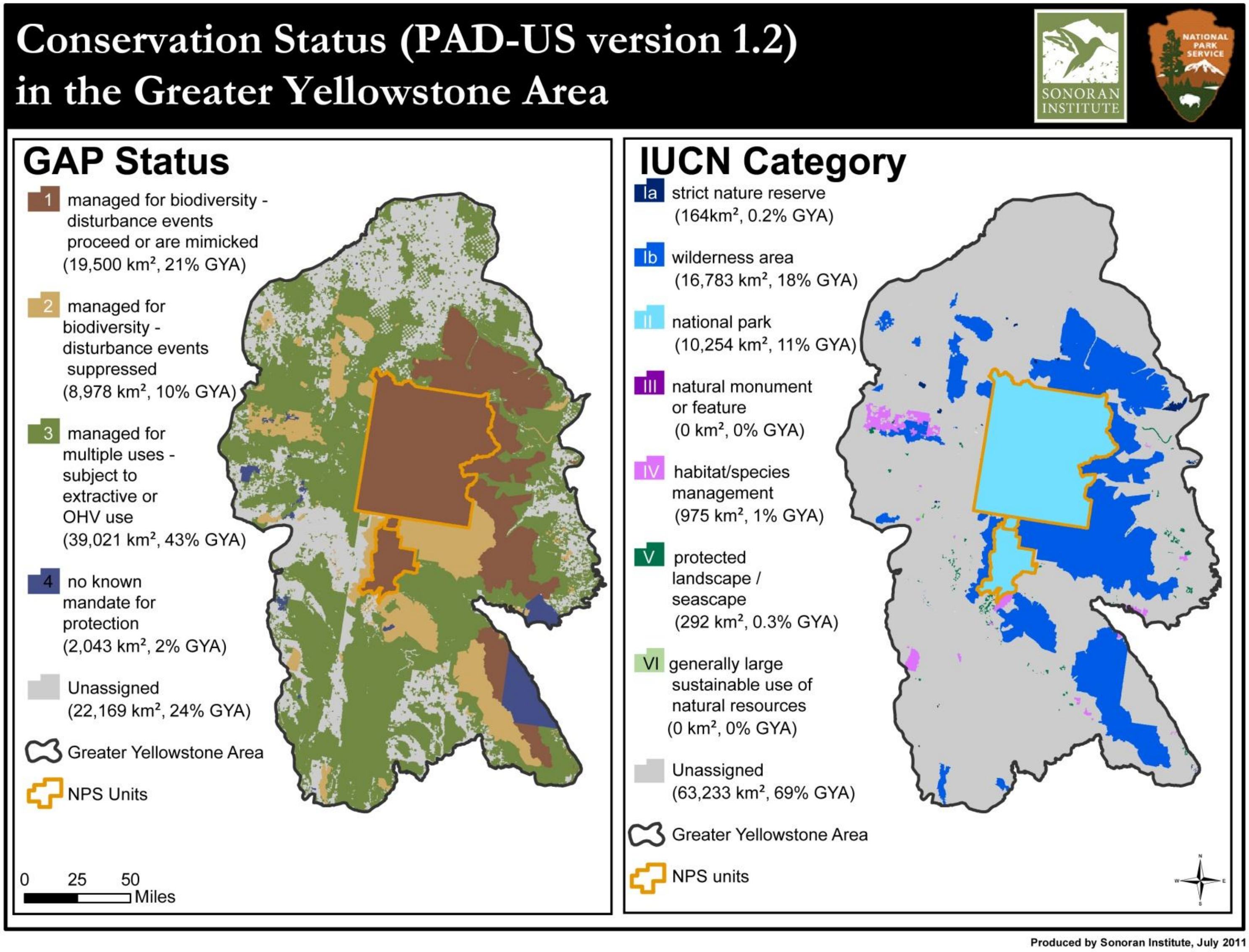


Figure 4.1.1. GAP Status and IUCN categories in the Greater Yellowstone Area.

4.2 Human Drivers

4.2.1 Population

Human population in the GYA was sparse at the turn of the 20th Century and has been steadily increasing since 1970. According to the U.S. Census Bureau, from 1990 to 2010, the population of the 34 counties in and surrounding the Greater Yellowstone Area grew by nearly 35% to over 930,000 residents (Figure 4.2.1). From 1990 to 2010, the population of census block groups in and near the GYA increased nearly 50%, from approximately 220,000 to roughly 323,000 (Figure 4.2.2). Growth within the census block groups was higher than the regional average. Much of the growth occurred as rural home development in subdivisions, as described below and shown in the SERGoM housing density estimates.

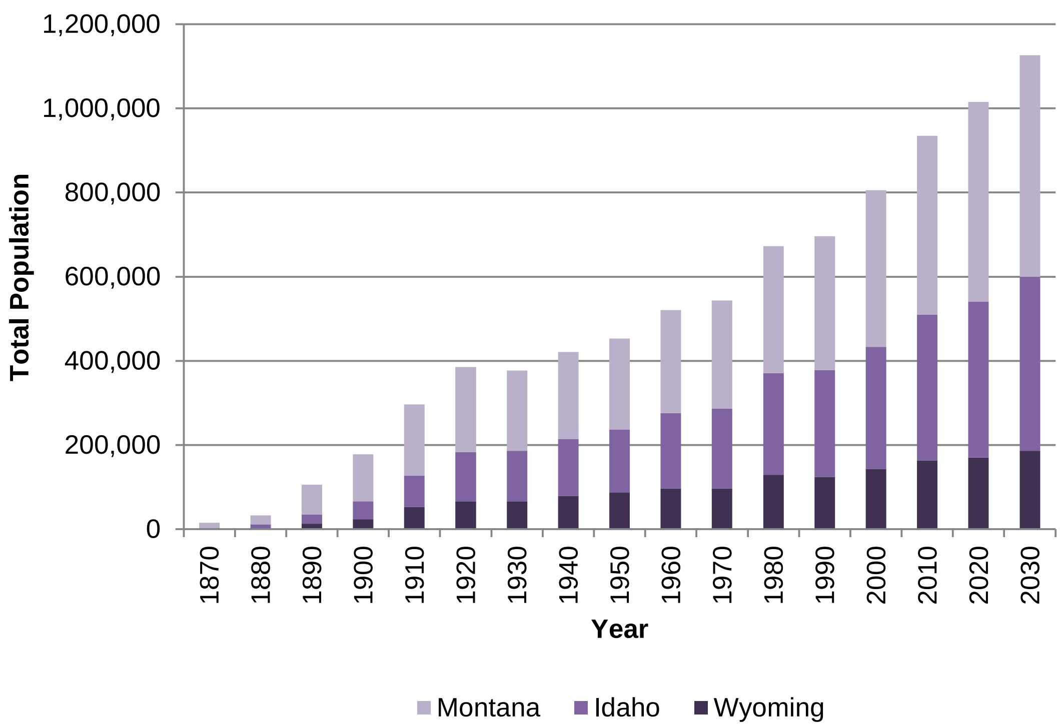


Figure 4.2.1. Total population, by state, in the Greater Yellowstone Area, 1870–2030.

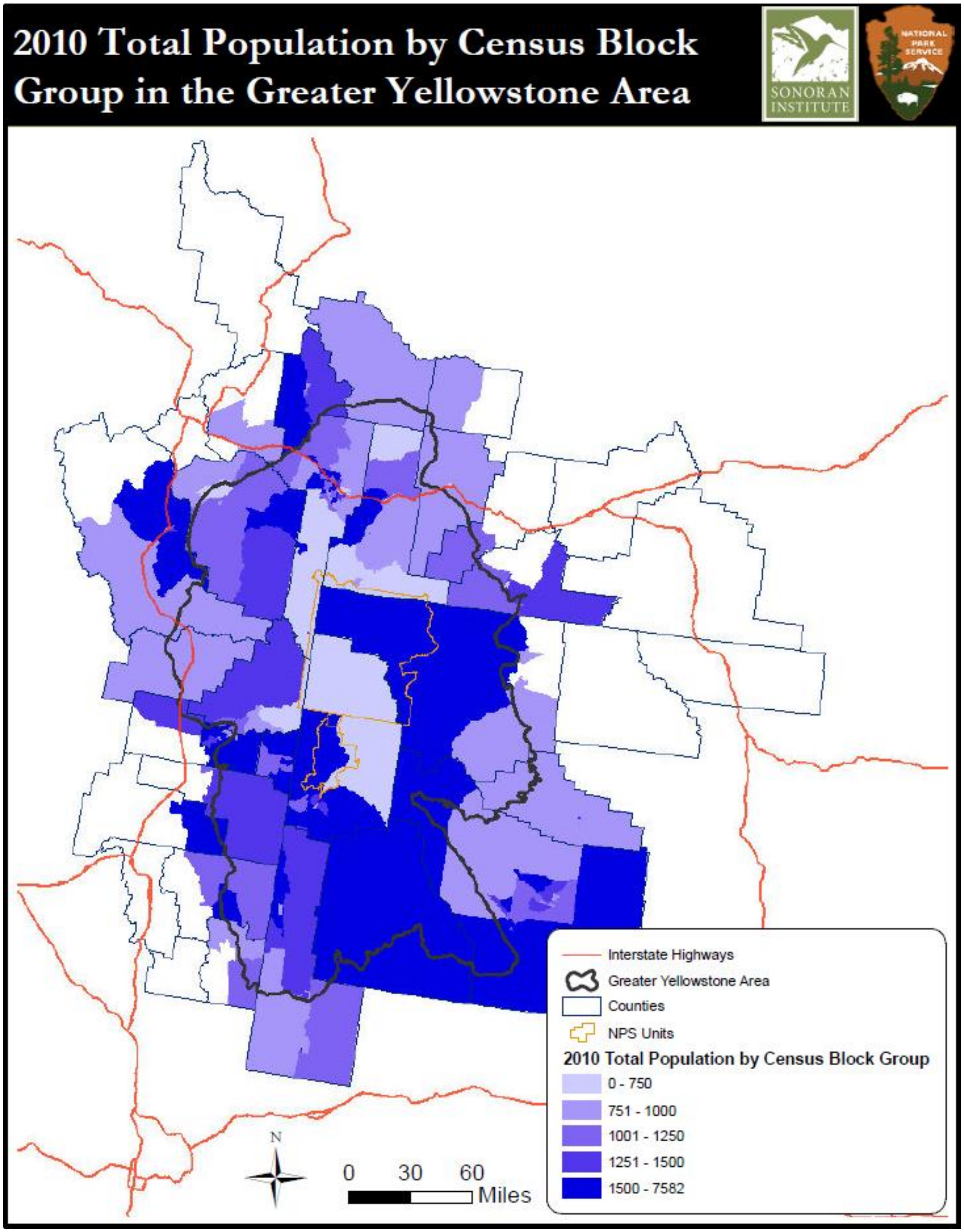


Figure 4.2.2. 2010 total population, by census block group, in and near the Greater Yellowstone Area.

4.2.2 Housing density

The amount of land considered "developable" by the Spatially Explicit Regional Growth Model (SERGoM) within the GYA is approximately 24,700 km^2 (~27% of the GYA). This estimate is subject to SERGoM criteria that exclude the potential for development on lands that are managed by the federal government or that are currently protected from development, but include Native American lands such as the Wind River Indian Reservation.

In 1970 over 25% of developable GYA land contained development that was predominantly rural residential (Figures 4.2.3 and 4.2.4). Using source data from 2005 or earlier the SERGoM calculated that nearly half of GYA developable land would be developed by 2010. The majority of development between 1970 and 2010 remained rural residential (6 or fewer housing units per square kilometer). Future projections forecast that development densities will increase with more land moving into the exurban residential category (7 – 145 units/km^2) but that rural residential will continue to dominate the Greater Yellowstone Area. The SERGoM does not predict a substantial increase in the total amount of land developed beyond 2010.

While housing development adjacent to public lands is of interest to many land managers, the SERGoM data source provided by NPScape is best suited for large landscape analysis (hundreds to thousands of square kilometers) rather than fine-scale analyses (few kilometers). An investigation of housing density on the edge of public lands likely requires the acquisition and interpretation of alternative data sources, including remote sensing imagery or a spatial home database based on data from county tax assessor's offices and/or state department of revenue similar to the database compiled by Gude and others (2006).

An important distinction exists between the greater amount of land reported using the SERGoM that is developed for housing and the lesser amount of developed land from the National Land Cover Dataset (NLCD) reported in section 4.3.1. This is due to the different data sources used for each type of assessment, and a result is that the NLCD developed classes reflect only the higher (exurban and urban) housing density classes from the SERGoM.

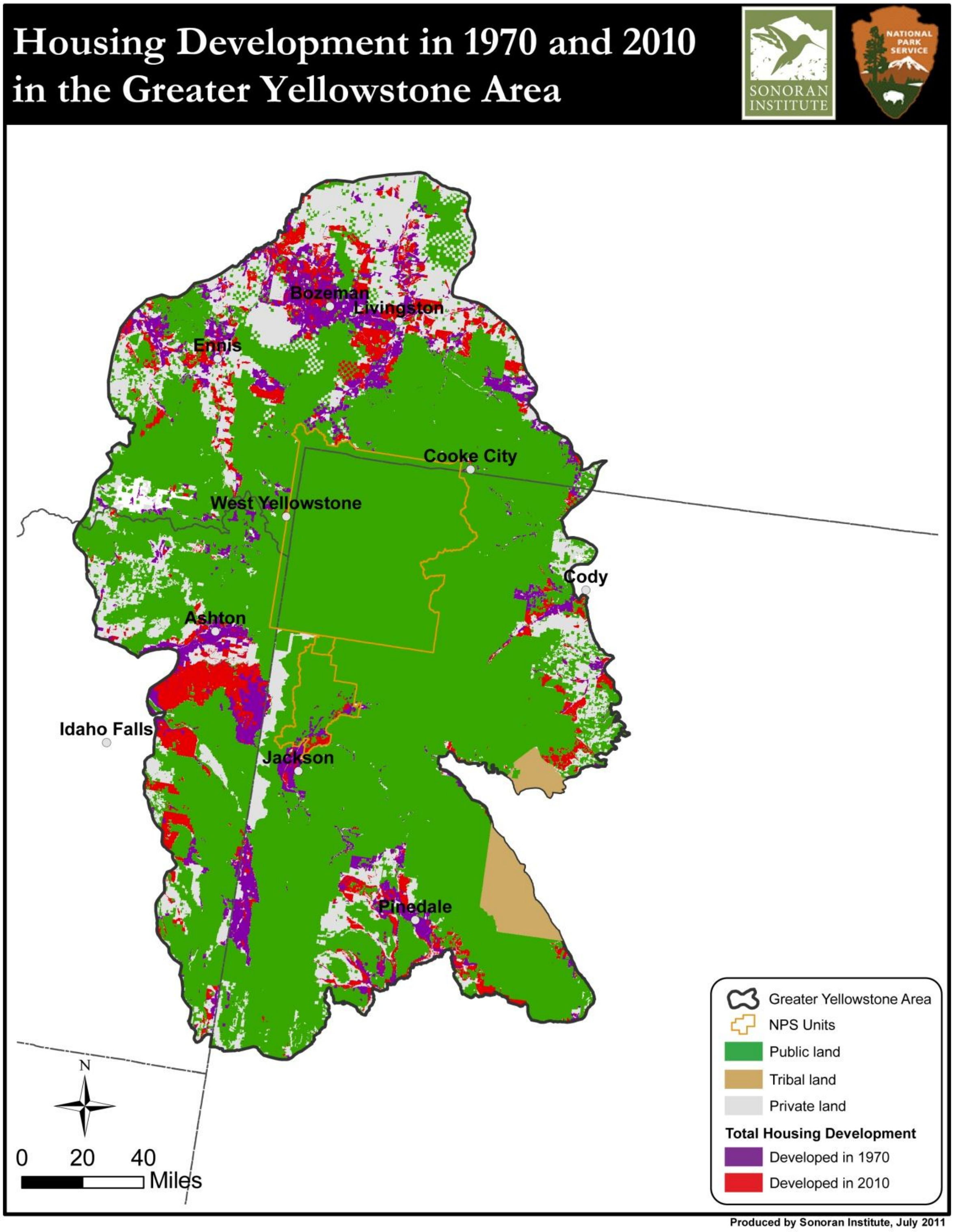


Figure 4.2.3. Total housing development in the Greater Yellowstone Area, 1970 and 2010 (right), with land ownership classes derived from PAD-US version 1.2.

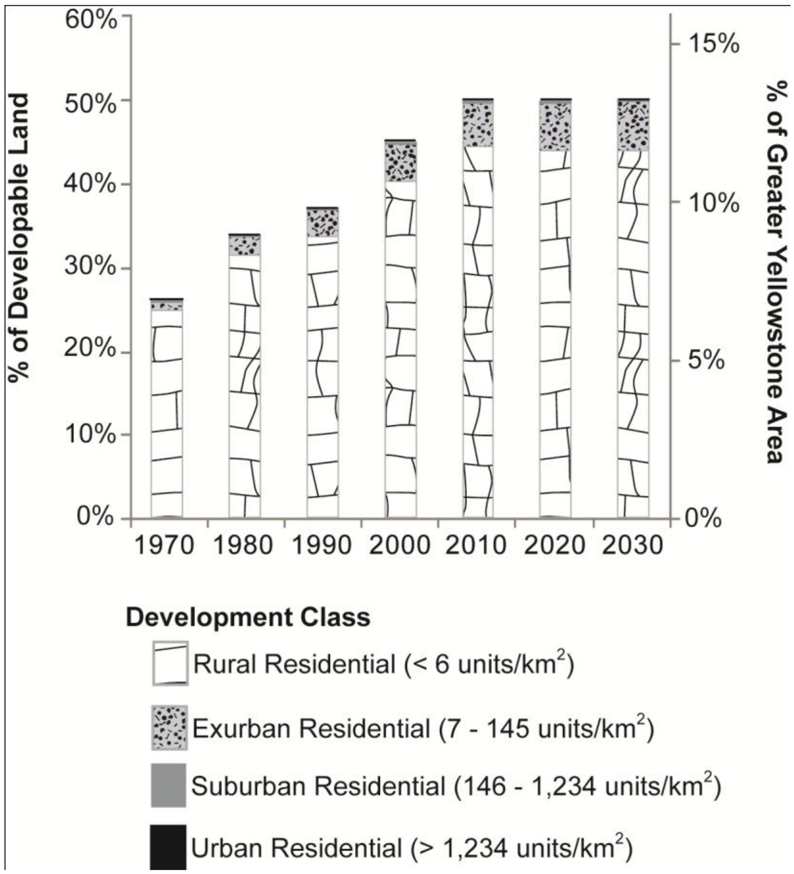


Figure 4.2.4. Housing density by class in the Greater Yellowstone Area, 1970-2030.

4.2.3 Roads and Traffic

Based on the Tele Atlas road information from 2005 available through ESRI, the overall road density in the GYA is roughly 0.5 km/km^2 (Figure 4.2.5). The density of major roads (interstates and highways) is 0.04 km/km^2 and the weighted road density is 0.6 km/km^2. In the weighted road calculation, interstate lengths were multiplied by five and highway lengths were multiplied by three to estimate traffic volume by major road type. Given that traffic data is only available for specific point locations, the weighted road density can be interpreted as a proxy for traffic where larger roads generally have higher traffic levels. Future land use monitoring reports, scheduled for five year intervals, will provide trend information about road density.

According to the Federal Highway Administration's 17 automatic traffic recorders outside NPS unit boundaries, the annual average daily traffic on roads in the region in 2005 ranged from 438 vehicles (on Idaho State Route 47 northeast of Ashton) to 6210 (on Big Sky Road, 1 mile west of US 191) (Figure 4.2.5). Highway 191 near Big Sky Road and US 26 in Jackson also had annual average daily traffic values greater than 5000 in 2005. Two additional points in Idaho had annual average daily traffic values of less than 1000 - US 89 west of SH-61 and State Route 32 north of Teton-Fremont County line.

In 2005, the annual daily traffic at traffic counters within Grand Teton National Park (NP) ranged from 645 vehicles at the north entrance (traffic coming south from John D. Rockefeller Memorial Parkway [MP]) to 3535 at the Gros Venture junction. The north and south entrances to John D. Rockefeller MP had an average traffic count of 706 and 603, respectively, in 2005. In contrast, the west entrance to John D. Rockefeller MP had an average daily traffic count of 25 in 2005. The northeast entrance at Yellowstone NP had the lowest amount of traffic among the park's entrances with an annual average daily traffic count of 166. When factoring in that the entrance was closed for par to the year, the average daily traffic count for May through October was 329, still the smallest amount within the park. The west entrance to Yellowstone NP had an average daily traffic count of 1139 for 2005, the highest count among the park's entrances. The May through October average daily traffic count was 2227 at the west entrance.

Roadless areas (at least 500 meters from a road) make up large portions of the GYA (~64%), especially within many lands managed by the National Park Service and U.S. Forest service in the central portion of the GYA (Figure 4.2.6). Patches of areas without roads of 100 km^2 or greater cover over 48,000 km^2 while smaller patches (< 100 km^2) of roadless areas cover nearly 10,500 km^2. While most areas within in GYA are at least 500 meters from a road, the dense network of roads areas near Bozeman, Montana, Ashton, Idaho, and Pinedale, Wyoming result in many areas that are less than 500 meters from a road (Figure 4.2.6).

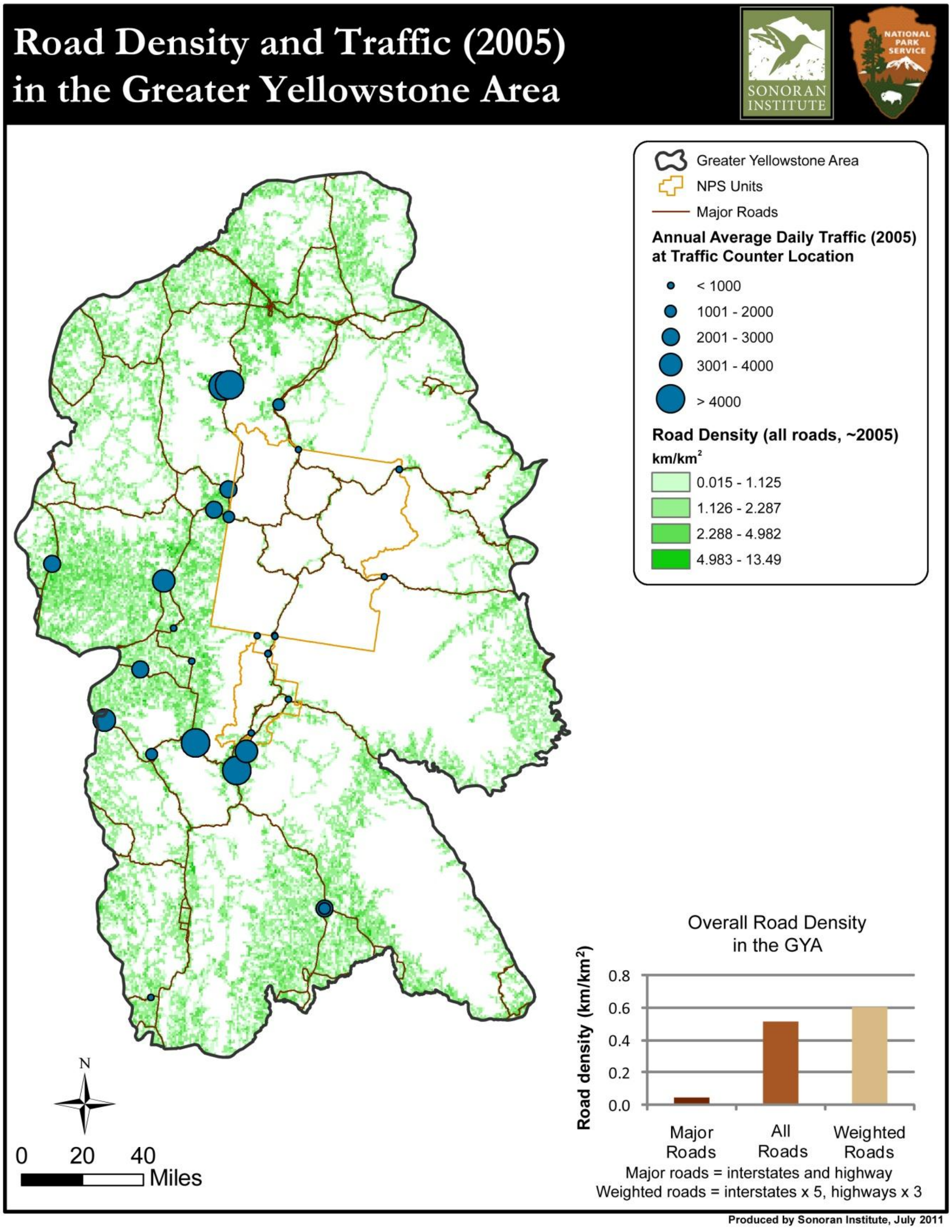


Figure 4.2.5. Estimated road density for all roads, with major roads shown, in the Greater Yellowstone Area.

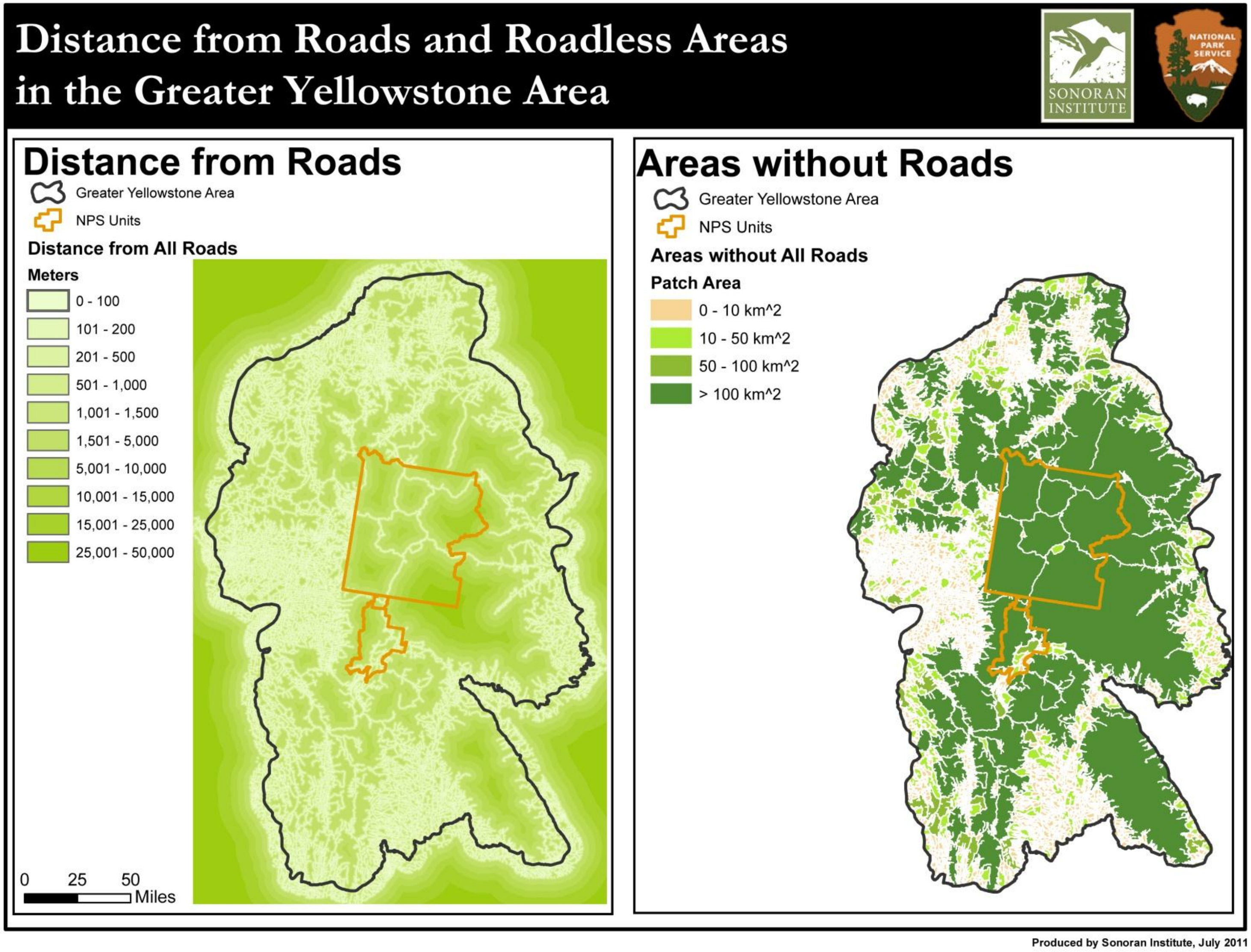


Figure 4.2.6. Estimated distance from roads (left) and patch size distributions of roadless areas, >500m from all roads (right) in the Greater Yellowstone Area.

4.2.4 Agriculture

Agriculture continues to be a significant land use in many of the 34 counties in and surrounding the GYA based on data from the National Agricultural Statistics Service (NASS) Census of Agriculture. Overall, the total amount of land in farms decreased from 2002 when 101,567 km^2 (44% of county area) were in farms to 2007 where 96,923 km^2 (42% of county area) were in farms (Table 4.2.1). Half of the counties had a decrease in land in farms from 2002 to 2007. Fremont County, Wyoming saw a decrease of 2846 km^2 of land in farms from 2002 to 2007. In contrast, Lewis and Clark County, Montana had an increase of 523 km^2 of land in farms.

According to the 2007 Census of Agriculture, the total land in farms within the 34 counties ranged from 214 km^2 to 11,374 km^2 and the proportion of county land in farms ranged from 2% to 96% (Figure 4.2.7). Teton County, Wyoming had the smallest amount of land in farms both in terms of actual land area and proportional to county area. Big Horn Canyon, Montana had the largest amount of land in farms while proportional to county area, Yellowstone County, Montana had the greatest proportion of land in farms. In the Census of Agriculture, a farm is “any place from which $1,000 or more or agricultural products were produced and sold, or normally would have been sold, during the census year” (NASS 2011). If a farm spans more than one county it is counted in both counties. Therefore, it is possible to report more land in farms than the total amount of land within a county.

In 2002 and 2007, the majority of land in farms was irrigated. A total of 63,804 km^2 were irrigated in 2002 within the 34 counties, accounting for 63% of the total land in farms in 2002. The total amount of irrigated land in farms increased to 64,197 km^2 within the 34 counties in 2007, which accounted for 66% of the total land in farms that year (Table 4.2.1).

Of the land in farms within the 34 counties, over 20% is cropland. In 2007, 21,371 km^2 of the land in farms were cropland. This represents approximately 9% of the total county area and 22% of the total land in farms. In 2002, roughly 10% (23,221 km^2) of the county area and 23% of the land in farms was in cropland.

Table 4.2.1. Land in farms and land in crops within the 34 counties in the Greater Yellowstone Area 2002 and 2007 (NASS 2011).

	2002	2007
Land in farms		
Total land in farms	101,567	96,923
Proportion of counties in farms	44%	42%
Land in irrigated farms		
Total land in irrigated farms	63,804	64,197
Proportion of farm land in irrigation	63%	66%
Land in non-irrigated farms		
Total land in non-irrigated farms	37,763	32,726
Proportion of farm land in non-irrigation	37%	34%
Land in cropland		
Total land in cropland	23,221	21,371
Proportion of counties in cropland	10%	9%
Proportion of farm land in cropland	23%	22%

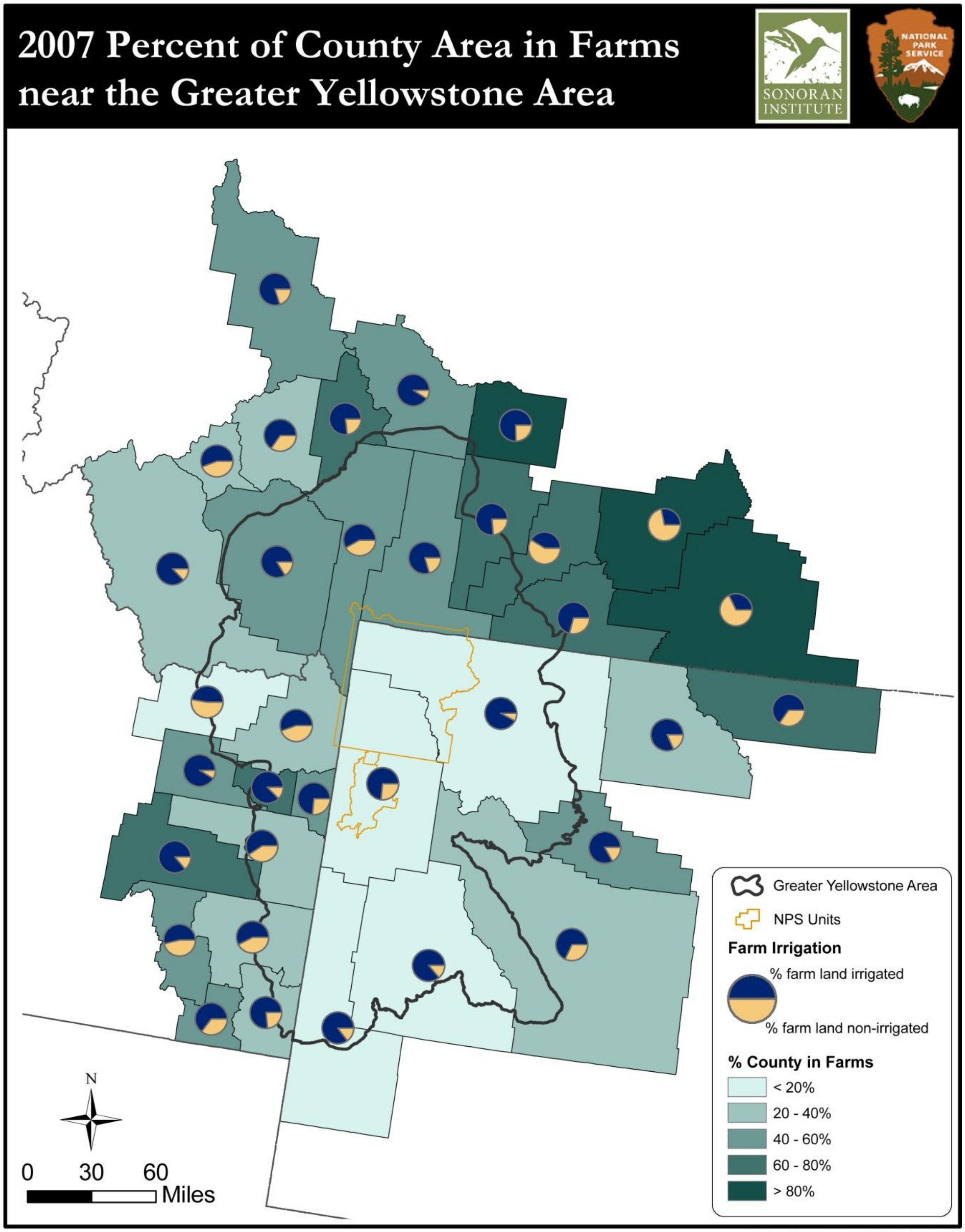
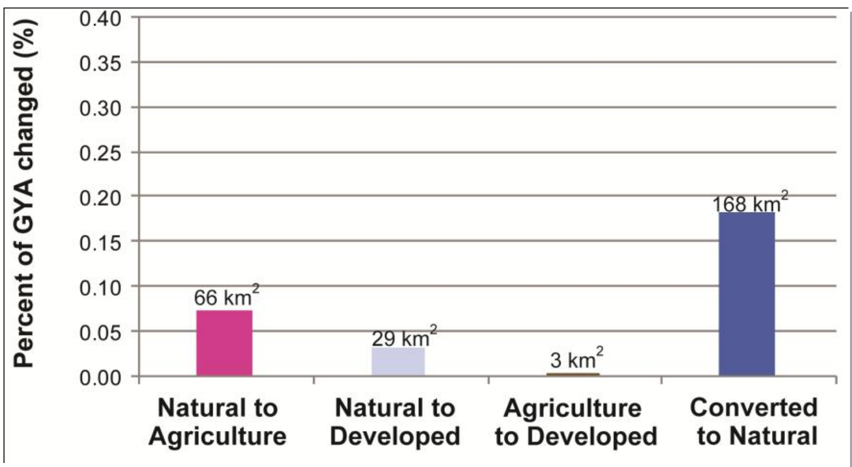


Figure 4.2.7. Proportion of county land in farms and proportion of farms in irrigation within the 34 counties in and near the Greater Yellowstone Area.

4.3 Natural System

4.3.1 Land cover and impervious surfaces

From 2001 to 2006, less than 300 square kilometers (km^2) changed from one broad-scale land cover category to the other (natural or converted; Figure 4.3.1). Approximately 94% of the GYA (86,318 km^2) was classified as natural land cover in 2001 and remained as natural land cover in 2006. Most of the land that was classified as converted (agriculture or development) in 2001 remained as converted lands in 2006 (~5.6%; 5,134 km^2). Approximately 29 km^2 (0.03% of GYA) changed from natural land cover to development between 2001 and 2006 and 66 km^2 (0.07%) changed from natural land cover to agriculture. From 2001 to 2006, roughly 3 km^2 changed from agriculture to development. According to methods described in section 3.3.6 of this report, approximately 0.2% of the GYA converted from agricultural uses in 2001 to natural cover in 2006. Nearly all of this area (156 of 168 km^2) represents changes from pasture and crop land to grass or shrub lands that are scattered across agricultural lands throughout the study area rather than localized in a particular place (map in Figure 4.3.1). The area within the 1988 Yellowstone fire perimeter showed little change in land cover type from 2001 to 2006.



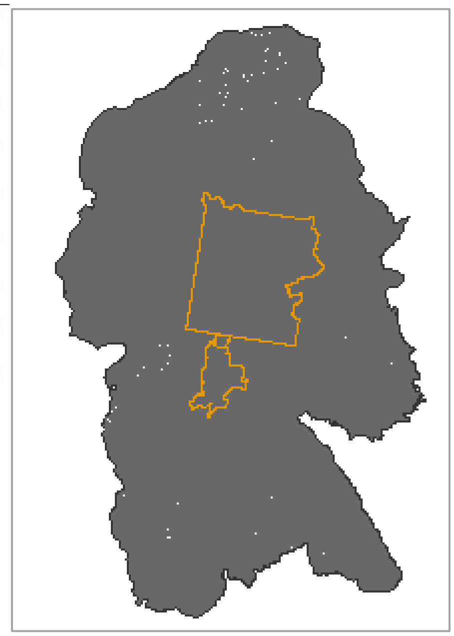


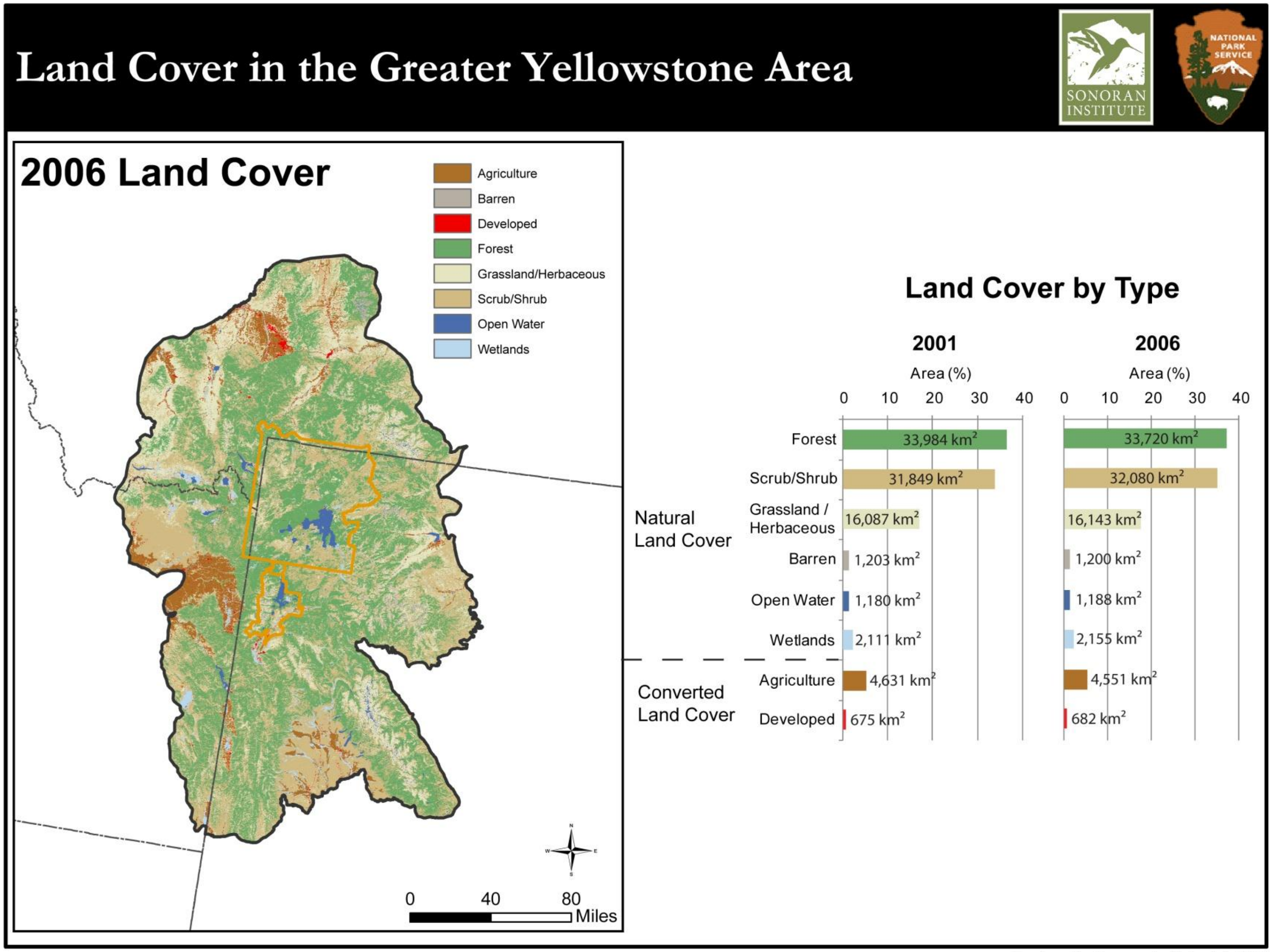
Figure 4.3.1. Land cover change from 2001-2006 in the Greater Yellowstone Area. White speckles in the map represent areas converted to natural according to a change analysis for this period.

The majority of the converted lands were agricultural lands (5% of GYA; Table 4.3.1; Figure 4.3.2) with a large portion of the agricultural lands occurring between Ashton and Idaho Falls, Idaho and outside of Bozeman, Montana. Agricultural land cover is fairly evenly split between cultivated agriculture and pasture/hay. The developed areas (0.7% of GYA) were concentrated in and near the towns of Bozeman and Livingston, Montana and Jackson, Wyoming. The majority of lands classified as developed were “developed, open spaces” followed by “developed, low intensity.” Forest and scrub/shrub dominated the natural land cover in 2001 and 2006 with approximately 37% forest cover and 35% scrub/shrub cover in the GYA. Most of the forest cover within the GYA is evergreen forest with small areas of deciduous and mixed forests. The grassland/herbaceous land cover type accounted for nearly 18% of the GYA in 2001 and in 2006.

In 2006, forests covered nearly half of the federally owned lands within the GYA (Table 4.3.2) while scrub/shrubs covered approximately one-third of the federally owned lands. Forests dominated (86%) lands owned by local governments while scrub/shrub (51%) and grasslands (29%) dominated state lands. Tribal lands were predominantly forest (38%) and scrub/shrub (39%) land cover. Scrub/shrub (35%) and grasslands (26%) were the predominant land cover on private lands but agriculture accounted for approximately 18% of the land cover on private lands.

Table 4.3.1. Detailed land cover (approximately Anderson Level II) in Greater Yellowstone Area, 2001 and 2006.

			2001		2006	
Broad-Scale Category	**Anderson Level I**	**Anderson Level II**	**km^2**	**% GYA**	**km^2**	**% GYA**
Natural	Forest	Deciduous Forest	1022	1.1	1031	1.1
		Evergreen Forest	32,839	35.8	32,566	35.5
		Mixed Forest	123	0.13	123	0.13
	Scrub/Shrub	Scrub/Shrub	31,849	34.7	32,080	35.0
	Grassland/Herbaceous	Grassland/Herbaceous	16,087	17.5	16,143	17.6
	Barren	Barren Land	1203	1.3	1200	1.3
	Open Water	Open Water	1079	1.2	1106	1.2
		Perennial Ice/Snow	101	0.11	82	0.09
	Wetlands	Emergent Herbaceous Wetlands	1277	1.4	1280	1.4
		Woody Wetlands	834	0.9	875	1.0
Converted	Agriculture	Cultivated Agriculture	2528	2.8	2495	2.7
		Pasture/Hay	2103	2.3	2056	2.2
	Developed	Developed Open Space	541	0.59	544	0.59
		Developed Low Intensity	111	0.12	114	0.12
		Developed Medium Intensity	21	0.02	23	0.02
		Developed High Intensity	1	0.002	2	0.002



Produced by Sonoran Institute, July 2011

Figure 4.3.2. Generalized land cover from NLCD (approximately Anderson Level I) in the Greater Yellowstone Area for circa 2001 and circa 2006.

Table 4.3.2. Generalized land cover (approximately Anderson Level I) by land ownership type in the Greater Yellowstone Area, circa 2006.

Ownership Type	Parameter	Land Cover							
		Agriculture	Barren	Developed	Forest	Grassland/ Herbaceous	Scrub/ Shrub	Water	Wetlands
Federal Land	Area (km^2)	56	1129	107	29039	8183	20743	985	949
	% of Ownership	< 0.1%	2%	< 0.1%	47%	13%	34%	2%	2%
	% GYA	< 0.1%	1%	< 0.1%	32%	9%	23%	1%	1%
Local Government Land	Area (km^2)	< 0.1	0	< 0.1	16	1	1	< 0.1	< 0.1
	% of Ownership	0.4%	-	1.7%	86.4%	5.9%	5.5%	-	0.1%
	% GYA	< 0.1%	-	< 0.1%	0.0%	< 0.1%	< 0.1%	-	< 0.1%
Native American Land	Area (km^2)	1	22	0	634	341	657	16	5
	% of Ownership	< 0.1%	1.3%	-	37.8%	20.3%	39.2%	1.0%	0.3%
	% GYA	< 0.1%	< 0.1%	-	0.7%	0.4%	0.7%	< 0.1%	< 0.1%
Non-Governmental Organization	Area (km^2)	0.2	0	0.03	5	4	16	0.1	6
	% of Ownership	0.8%	-	0.1%	16.0%	14.4%	49.8%	0.2%	18.7%
	% GYA	< 0.1%	-	< 0.1%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	< 0.1%
State Land	Area (km^2)	90	2	26	520	1126	1987	50	89
	% of Ownership	2.3%	< 0.1%	0.7%	13.4%	28.9%	51.1%	1.3%	2.3%
	% GYA	0.1%	< 0.1%	< 0.1%	0.6%	1.2%	2.2%	0.1%	0.1%
Private	Area (km^2)	4401	47	545	3489	6311	8547	126	1060
	% of Ownership	17.9%	0.2%	2.2%	14.2%	25.7%	34.8%	0.5%	4.3%
	% GYA	4.8%	0.1%	0.6%	3.8%	6.9%	9.3%	0.1%	1.2%

The total amount of impervious surfaces within the GYA, as estimated by the 2006 NLCD, is approximately 1.1% (Table 4.3.3). The GYA was dominated by the 0-2% impervious class with 90,585 km^2 in the category (nearly 99% of the GYA). This suggests that impervious surfaces are not impacting aquatic and riparian resources in the GYA, though impervious surfaces may be a concern at specific sites. Most of the impervious surfaces occurred along roads and interstates and in the Bozeman, Montana area.

Table 4.3.3. Impervious surfaces in the Greater Yellowstone Area, 2006.

Impervious Surface Class	Total Area (km^2)	% GYA
0-2%	90,585	98.76
2-4%	378	0.41
4-6%	163	0.18
6-8%	112	0.12
8-10%	82	0.09
10-15%	132	0.14
15-25%	130	0.14
25-50%	107	0.12
50-100%	31	0.03

4.3.2 Wildlife habitat and corridors

<u>Mule Deer</u>

Overall, approximately 55,000 km^2 (60% of GYA) within the GYA is mapped as habitat for mule deer by the Utah State University Mule Deer Mapping Project (Figure 4.3.3). Nearly 34,000 km^2 (37% of GYA) is considered winter range habitat for mule deer. Winter range is the overall range where 90 percent of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site-specific period of winter. The winter concentration habitat area, portions of the winter range where densities are at least 200% greater than the surrounding winter range density, covers approximately 1% (920 km^2) of the GYA. The year-round population habitat area, which provides year-round range, covers over 20,000 km^2 (22% of GYA).

The majority of year-round mule deer habitat occurs on lands managed by the U.S. Forest Service (11,895 km^2, Table 4.3.4) with approximately 4,100 km^2 of year-round habitat occurring on private lands. The Bureau of Land Management has the largest amount of winter concentration mule deer habitat of any land manager (524 km^2) even though it has a relatively small amount of the winter range (3040 km^2). Most of the mule deer winter range occurs on U.S. Forest Service lands (13,913 km^2) and private lands (12,557 km^2).

Forested land cover accounts for the greatest amount of land cover by type (~9,000 km^2 [44%]) of year-round habitat within the GYA (Figure 4.3.4). Nearly all of the forested land cover (99%) identified as mule deer habitat is evergreen forest. Scrub/shrub and grassland/herbaceous land cover types account for 5606 km^2 and 4367 km^2, respectively, of the year-round mule deer habitat. Agricultural and developed land cover types contain a combined 464 km^2 of year-round habitat. The winter range habitat primarily occurs on scrub/shrub (12,367 km^2, 2% of habitat type), forest (9804 km^2), and grassland/herbaceous (7001 km^2) land cover types. Agricultural and developed land cover types contained approximately 7% of the winter range habitat (2364 km^2). Scrub/shrub land cover accounts for the largest proportion of winter concentration mule deer habitat (705 km^2, 69% of habitat type) followed by grassland/herbaceous (100km^2, 10%) and agriculture (98 km^2, 10%).

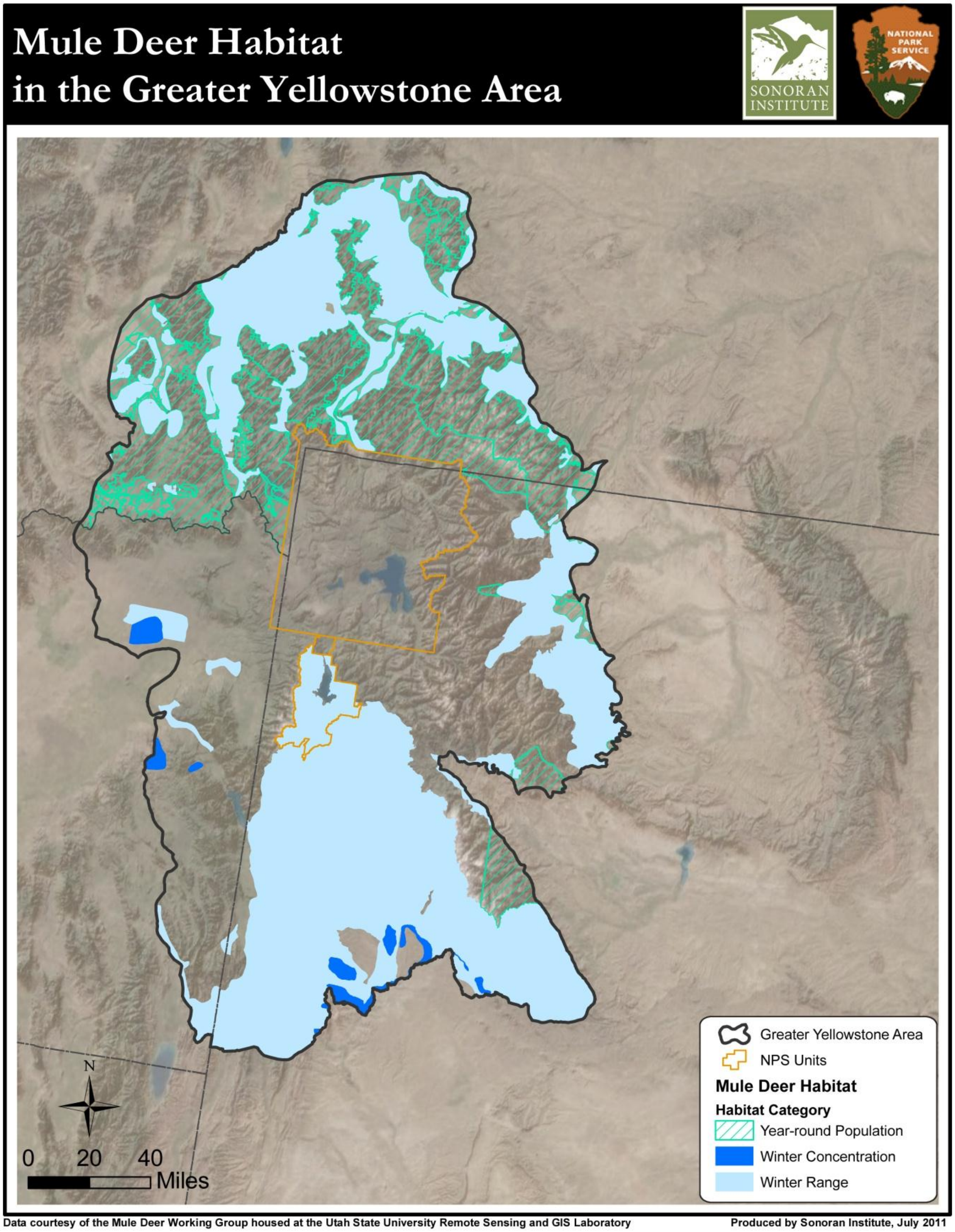


Figure 4.3.3. Mule deer habitat by habitat type in the Greater Yellowstone Area according to the Utah State University Mule Deer Mapping Project.

Table 4.3.4. Mule deer habitat by land management within the Greater Yellowstone Area.

Manager	Area by Habitat Type (km^2)		
	Year-round Population	Winter Concentration	Winter Range
Federal			
Bureau of Land Management	992	524	3040
Bureau of Reclamation	10	0	6
Fish and Wildlife Service	188	0	106
Forest Service	11,895	24	13,913
National Park Service	2	0	1105
Other Federal Land	0	0	19
Native American			
Wind River Indian Reservation	1245	2	427
State			
State Fish and Wildlife	125	43	244
State Park & Recreation	33	0	26
State Land Board	604	31	1300
State Department of Land	0	18	92
State Department of Natural Resources	34	0	0
Local Government			
City Land	15	0	3
Non-Governmental Organization			
The Nature Conservancy	1	0	24
Private			
Private Non-profit	1	0	46
Private Conservation	546	0	1490
Private	4101	374	11,021

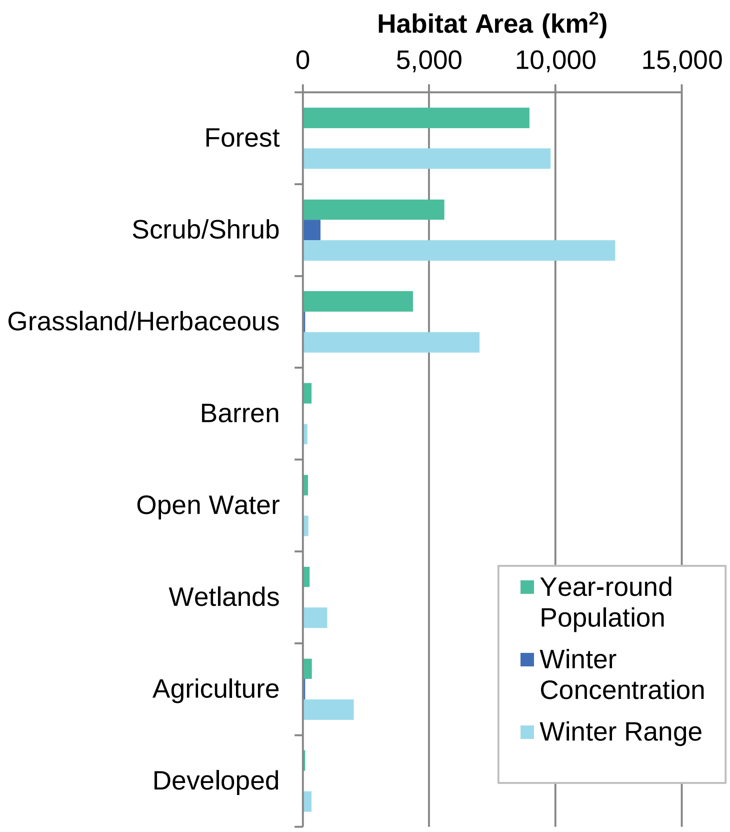


Figure 4.3.4. Mule deer habitat by habitat type and general land cover type in the Greater Yellowstone Area.

Grizzly Bear

Grizzly bears once occurred throughout the western United States and north through Canada to northern Alaska and south into northern Mexico (Rausch 1963). But human developments and activities like livestock grazing, mining, and hunting decreased the grizzlies' range nearly 98% (Mattson et al. 1995). Grizzly bears utilize forested areas and non-forested meadows. In 1975, grizzly bear populations in the western U.S. were listed as a threatened species under the Endangered Species Act. In 2007, grizzly bears in the GYA were removed from threatened species status by the U.S. Fish and Wildlife Service (USFWS 2007). However, a lawsuit and subsequent court ruling in 2009 restored the threatened species status, pending appeal.

Today, humans continue to pose a threat to grizzly bears as more people develop and use the bears' natural habitat. Housing development and associated roads can displace bears and fragment habitats (WCS 2011b). Humans cause the majority of grizzly bear mortalities in the Greater Yellowstone Ecosystem (GYE). For example, 24 of the 31 reported grizzly mortalities in the Greater Yellowstone Ecosystem in 2009 were human caused (hunting-related, self-defense, management removal, and vehicle collisions; IGBST 2011b).

Walker and Craighead (1997) modeled grizzly bear core habitat patches of greater than 50 and 250 km2. Approximately 14,000 km2 were identified as grizzly bear core habitat patches of 50 km2 or greater and over 8,900 km2 were mapped as core habitat patches of at least 250 km2 (Figure 4.3.5). Roughly 90% of the area identified as core habitat is managed by federal land management agencies, predominantly by the U.S. Forest Service. Most of the land cover within grizzly core habitat is forest (~60%) and scrub/shrub (~30%).

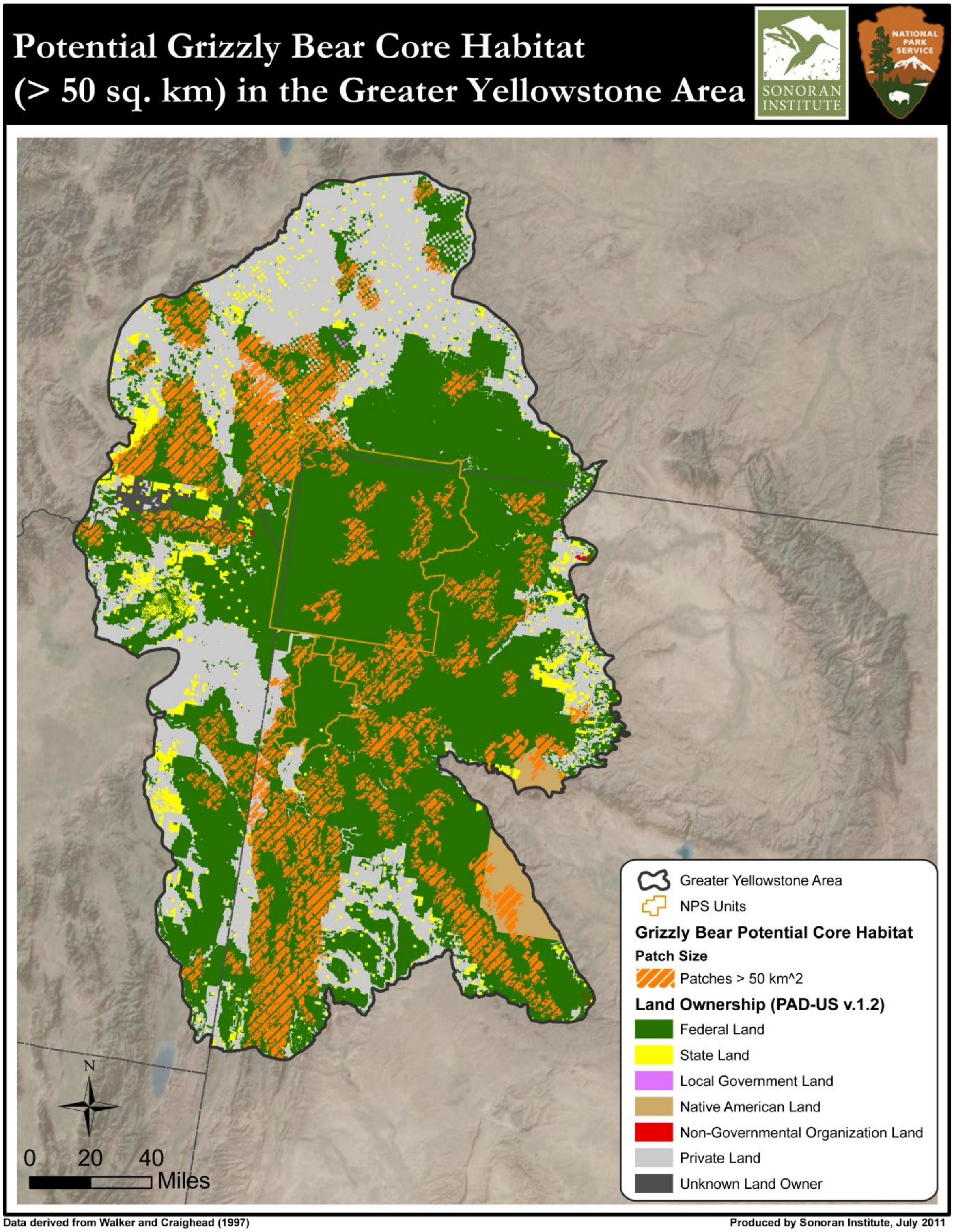


Figure 4.3.5. Estimated grizzly bear core habitat in the Greater Yellowstone Area, as modeled by the Walker and Craighead (1997).

Wolverine

The current range of wolverines extends south from Alaska and Canada into mountainous regions of the western United States (USFWS 2011), including the GYA where wolverines utilize alpine and boreal habitats (GYSLC 2010). By the early 1900s, the distribution of wolverines substantially decreased due to predator control efforts and commercial trapping (GYSLC 2010). Wolverines require persistent and deep spring snow for dens to protect kits. Due to the wolverine's reliance on high elevation habitat and dependence on spring snowpack, climate change poses a threat to wolverines in the GYA (USFWS 2011).

Forty percent (36,568 km^2) of the GYA is considered wolverine habitat according to habitat estimates from the Wildlife Conservation Society (Figure 4.3.6). Forested land cover accounts for 53% of the land cover within wolverine habitat (19,401 km^2; Figure 4.3.7). Nearly all of the forested land cover (98%) identified as wolverine habitat is evergreen forest. Scrub/shrub and grassland/herbaceous land cover types account for 10,322 km^2 and 5,454 km^2, respectively, of the wolverine habitat. Agricultural (4 km^2) and developed (12 km^2) land cover types account for less than 1% of the wolverine habitat within the GYA. The majority (>90%) of wolverine habitat occurs on federally managed lands, predominantly on land managed by the U.S. Forest Service (29,114 km^2) and the National Park Service (4,117 km^2). Just over 3% (1,125 km^2) of wolverine habitat occurs on private lands.

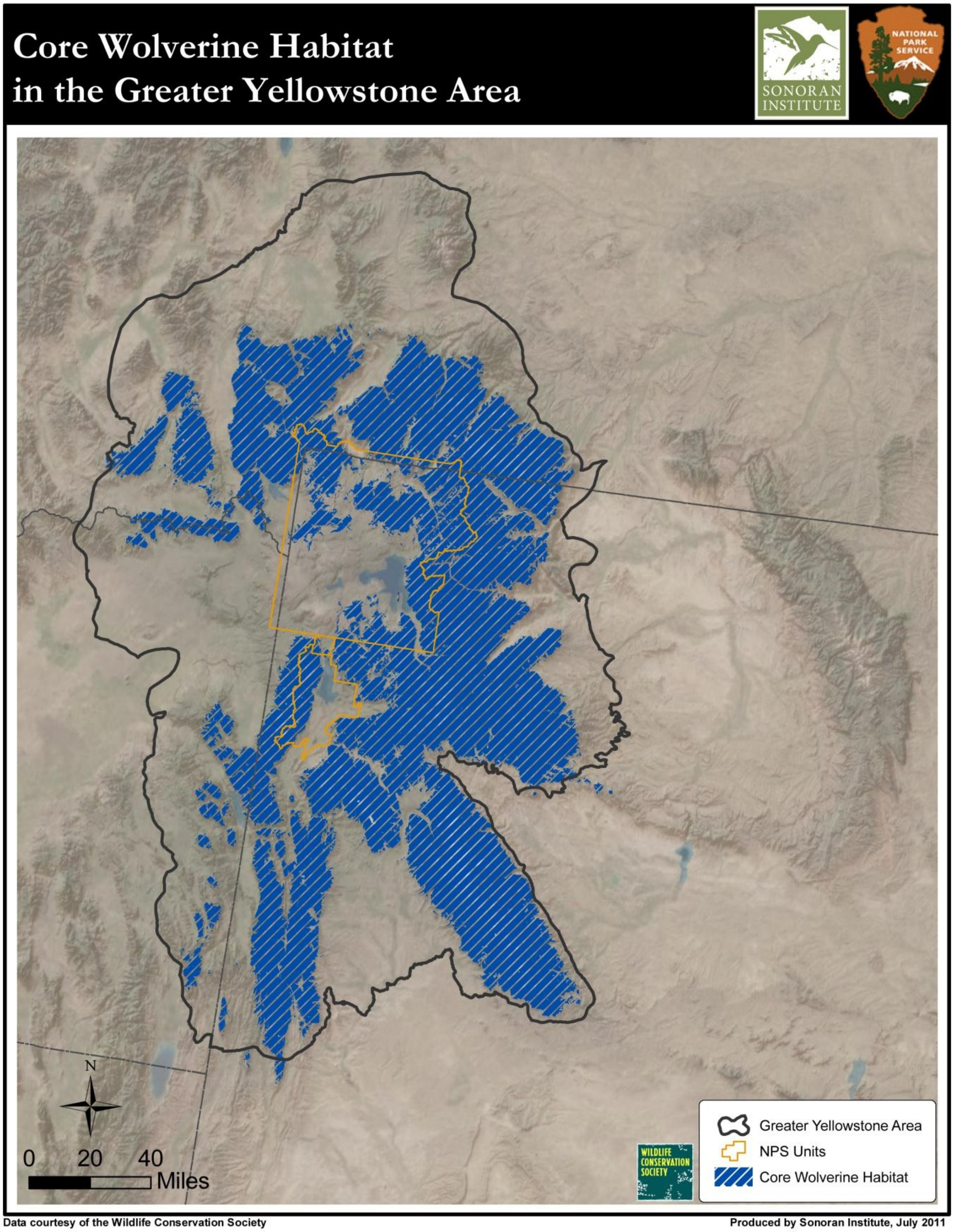


Figure 4.3.6. Wolverine habitat in the Greater Yellowstone Area, as modeled by the Wildlife Conservation Society.

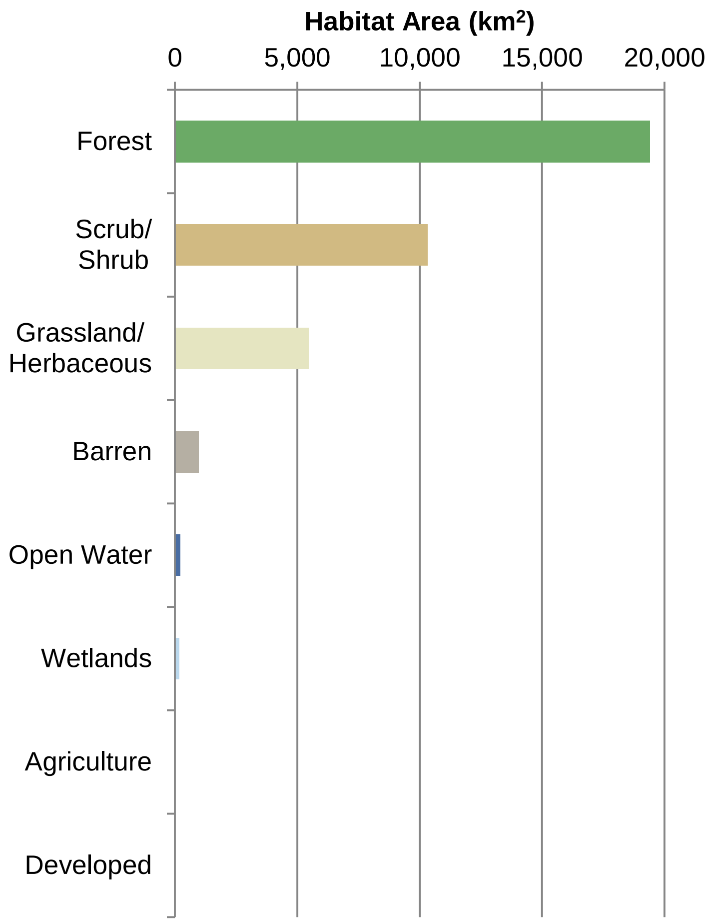


Figure 4.3.7. Wolverine habitat by general land cover type in the Greater Yellowstone Area.

Ungulate Migratory Routes

According to Wildlife Conservation Society estimates, there are 16,527 km (10,272 miles) of ungulate migratory routes in the GYA (Figure 4.3.8). Elk and mule deer have the longest migratory routes within the GYA. The source data from the Wildlife Conservation Society also provides a comparative estimate of the degree to which those routes are threatened by human activities. The mean threat value, which ranges from 0 to 100, estimates the overall impact to the route by deleterious human uses (WCS 2011a). A higher threat value corresponds to a higher threat level. On average, pronghorn (45) and moose (44) have the most highly threatened migration corridors within the GYA, as compared to bighorn sheep (20), elk (24) and mule deer (37).

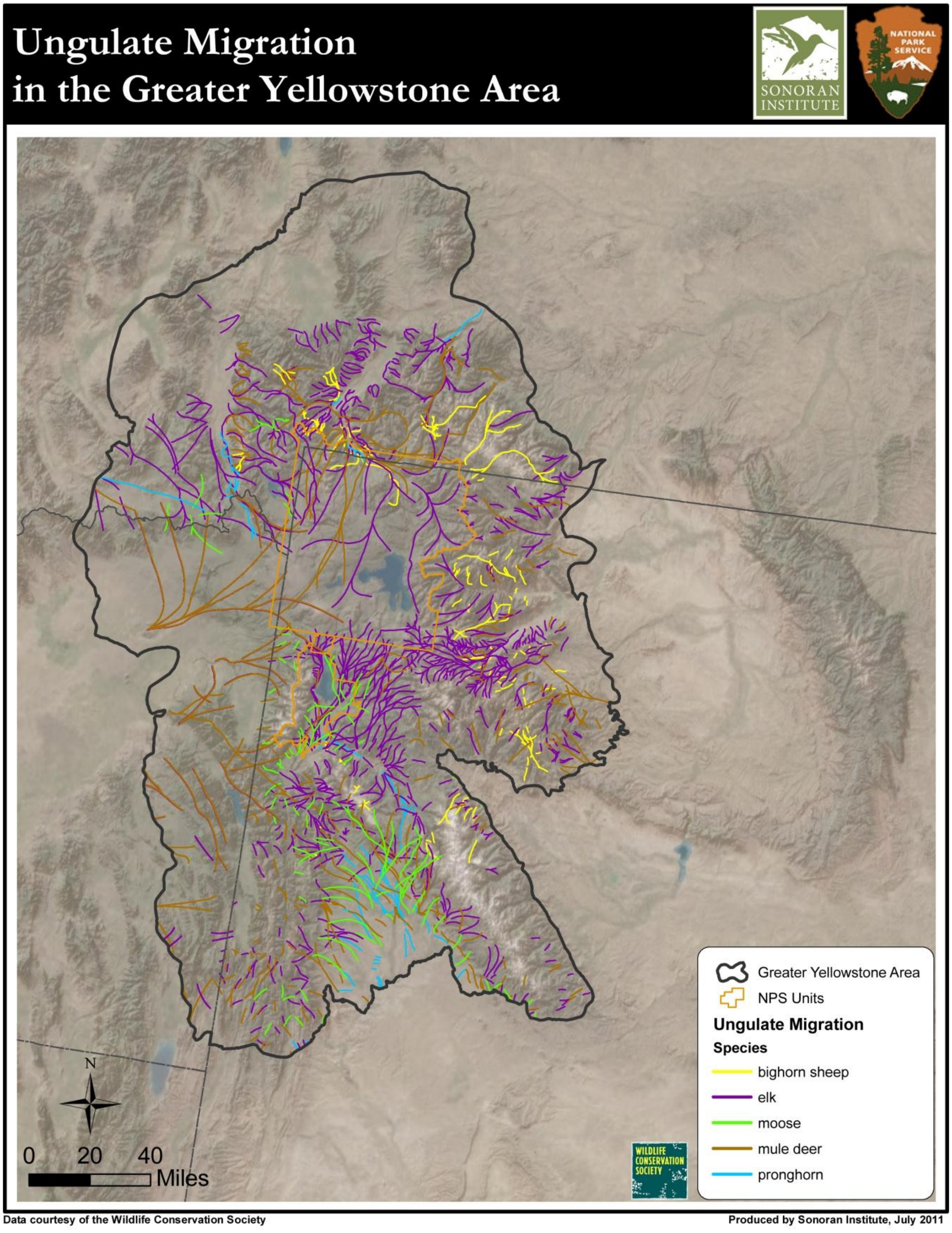


Figure 4.3.8. Ungulate migration routes in the Greater Yellowstone Area, based on data from the Wildlife Conservation Society.

5 Conclusions

The majority of lands within the Greater Yellowstone Area (GYA) are public lands managed by the federal government (67%) and the U.S. Forest Service manages nearly half of the GYA. The National Park Service is the second largest federal land manager. Private lands account for roughly 27% of the GYA and a number of private lands are designated as formal conservation lands. According to the PAD-US database (version 1.2), lands managed for biodiversity where disturbance events are allowed to proceed or are mimicked (GAP Status 1) account for 21% of the area of analysis and lands managed for biodiversity where disturbance events are suppressed (GAP Status 2) account for 10% of the GYA. Forty-three percent of the lands within the GYA are managed for multiple uses – subject to extractive or OHV uses (GAP Status 3).Of the lands that were assigned an IUCN category, most (18%) were wilderness areas (Ib) and national parks (11%, II). USFS wilderness study areas, BLM research natural areas, and The Nature Conservancy preserves were assigned to the IUCN category Ia (strict nature reserve) but accounted for less than 1% of the lands within the GYA.

Human population in the GYA continues to increase. According to the U.S. Census Bureau, from 1990 to 2010, the population of the 34 counties in and surrounding the Greater Yellowstone Area grew by nearly 35% to over 930,000 residents. The majority of development between 1970 and 2010 was rural residential development (< 6 units/km2). Future projections forecast that development densities will increase with more land moving in to the exurban residential category (7 – 145 units/km2) but that rural residential will continue to dominate the GYA.

The overall road density in the GYA is roughly 0.5 km/km^2, based on the Tele Atlas road information from circa 2005. The density of major roads (interstates and highways) is 0.04 km/km^2 and the weighted road density is 0.6 km/km^2. Roadless areas (at least 500 meters from a road) make up large portions of the GYA (~64%). Future land use monitoring reports, scheduled for five year intervals, will provide trend information about road density. In 2005, the annual average daily traffic on roads recorded by 17 automatic traffic recorders outside NPS units ranged from 438 vehicles (on Idaho State Route 47 northeast of Ashton) to 6210 (on Big Sky Road, 1 mile west of US 191).

Agriculture continues to be a significant land use in the GYA with 2% to 96% of the individual county area in farms in 2007. The majority of land in farms was irrigated and less than one-quarter of the land in farms is cropland.

From approximately 2001 to 2006, there was very little change in the broad-scale natural and converted land cover. In 2006, the majority of land in the GYA was natural land cover (94%), with less than 6% of the land as agriculture or developed. Agricultural land cover is fairly evenly split between cultivated agriculture and pasture/hay. The developed areas were concentrated in and near the towns of Bozeman and Livingston, Montana and Jackson, Wyoming. The majority of lands classified as developed were “developed, open spaces” followed by “developed, low intensity.” In 2006, forests covered nearly half of the federally owned lands within the GYA, unsurprising since the U.S. Forest Service is the dominant federal land manager. In contrast, scrub/shrub and (35%) and grasslands (26%) were the predominant land cover on private lands but agriculture accounted for approximately 18% of the land cover on private lands.

Approximately 55,000 km^2 (60% of GYA) within the GYA is mapped as habitat for mule deer. Forested land cover accounts for the greatest amount of land cover by type (~9,000 km^2 [44%]) of year-round mule deer habitat within the GYA. Agricultural and developed land cover types contain a combined 464 km^2 of year-round habitat. The winter range habitat primarily occurs on scrub/shrub (12,367 km^2, 2% of habitat type), forest (9804 km^2), and grassland/herbaceous (7001 km^2) land cover types. Agricultural and developed land cover types contained approximately 7% of the winter range habitat (2364 km^2). Scrub/shrub land cover accounts for the largest proportion of winter concentration mule deer habitat (705 km^2, 69% of habitat type) followed by grassland/herbaceous (100 km^2, 10%) and agriculture (98 km^2, 10%).

The Wildlife Conservation Society modeled grizzly bear core habitat patches of greater than 50 and 250 km^2. Approximately 14,000 km^2 were identified as grizzly bear core habitat patches of 50 km^2 or greater and over 8,900 km^2 were mapped as core habitat patches of at least 250 km^2. Roughly 90% of the area identified as core grizzly bear habitat is managed by federal land management agencies, predominantly by the U.S. Forest Service. Most of the land cover within grizzly core habitat is forest (~60%) and scrub/shrub (~30%).

Forty percent (36,568 km^2) of the GYA is considered wolverine habitat according to habitat estimates from the Wildlife Conservation Society and forested land cover accounts for 53% of the land cover within wolverine habitat (19,401 km^2). The majority (> 90%) of wolverine habitat occurs on federally managed lands, predominantly on land managed by the U.S. Forest Service (29,114 km^2) and the National Park Service (4,117 km^2). Just over 3% (1,125 km^2) of wolverine habitat occurs on private lands.

According to Wildlife Conservation Society estimates, there are 16,527 km (10,272 miles) of ungulate migratory routes in the GYA (Figure 4.3.8). Elk and mule deer have the longest migratory routes within the GYA.

While we were able to acquire consistent wildlife habitat data for some species, we encountered numerous datasets for a given species that were inconsistent across state and jurisdictional boundaries, utilized different methodologies and/or had different habitat type definitions. Given our reliance on consistent, publically-available, pre-existing data, the integration of NPScape landscape dynamics data with wildlife information is limited.

The landscape dynamics data presented in this report and available through the NPS Greater Yellowstone Network can be used to interpret management questions related to human use of backcountry areas, transportation planning, air travel, night skies, soundscapes and invasive species. However, due to time and budgetary constraints, we were not able to address those questions in this report.

Additional data acquisition and interpretation may be necessary for long-term landscape dynamics monitoring. Many of the habitats and vegetation types of concern within the GYA are too spatially restricted or taxonomically detailed, such as whitebark pine, for consistent or reliable mapping in a national effort such as NPScape. Therefore, the acquisitions, classification, and interpretation of additional imagery sources should be considered. However, the broad-scale data products and tools provided by NPScape form a solid foundation for long-term monitoring.

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Appendix A: NLCD 2001 and 2006 land cover classes and reclassification for calculating percent of natural and converted land cover (NPS 2010b; MRLC 2011).

Anderson Level I	Anderson Level II	Natural / Converted
1 Water	11 Open Water	2 Natural
	12 Perennial Ice/Snow	2 Natural
2 Developed	21 Developed, Open Space	1 Converted
	22 Developed, Low Intensity	1 Converted
	23 Developed, Medium Intensity	1 Converted
	24 Developed, High Intensity	1 Converted
3 Barren	31 Barren Land	2 Natural
4 Forest	41 Deciduous Forest	2 Natural
	42 Evergreen Forest	2 Natural
	43 Mixed Forest	2 Natural
5 Shrub / Shrub	51 Dwarf Scrub	2 Natural
	52 Scrub/Shrub	2 Natural
7 Grassland / Herbaceous	71 Grassland/Herbaceous	2 Natural
	72 Sedge Herbaceous	2 Natural
	73 Lichens	2 Natural
	74 Moss	2 Natural
8 Agriculture	81 Pasture/Hay	1 Converted
	82 Cultivated Crops	1 Converted
9 Wetlands	90 Woody Wetlands	2 Natural
	95 Emergent Herbaceous Wetland	2 Natural

Appendix B: 2001-2006 land cover change reclassification scheme (MRLC 2011).

NLCD Change Class	Change Class
1 Open Water	2 Natural
2 Developed	1 Converted
3 Barren	2 Natural
4 Forest	2 Natural
5 Shrub/Scrub	2 Natural
7 Grassland/Herbaceous	2 Natural
8 Agriculture	1 Converted
9 Wetlands	2 Natural
11 Perennial Ice/Snow to Perennial Ice/Snow	2 Natural
13 Open Water to Barren Land	2 Natural
14 Open Water to Deciduous Forest	2 Natural
15 Open Water to Shrub/Scrub	2 Natural
17 Open Water to Grassland/Herbaceous	2 Natural
18 Open Water to Cultivated Crops	3 Natural to Agriculture
19 Open Water to Emergent Herbaceous Wetlands	2 Natural
27 Developed, Open Space to Grassland/Herbaceous	1 Converted
31 Barren Land to Open Water	2 Natural
34 Barren Land to Deciduous Forest	2 Natural
35 Barren Land to Shrub/Scrub	2 Natural
37 Barren Land to Grassland/Herbaceous	2 Natural
38 Barren Land to Pasture/Hay	3 Natural to Agriculture
39 Barren Land to Emergent Herbaceous Wetlands	2 Natural
41 Deciduous Forest to Open Water	2 Natural
42 Evergreen Forest to Developed, Medium Intensity	4 Natural to Urban
43 Evergreen Forest to Barren Land	2 Natural
45 Deciduous Forest to Shrub/Scrub	2 Natural
47 Deciduous Forest to Grassland/Herbaceous	2 Natural
48 Deciduous Forest to Cultivated Crops	3 Natural to Agriculture
49 Deciduous Forest to Emergent Herbaceous Wetlands	2 Natural
51 Shrub/Scrub to Open Water	2 Natural
52 Shrub/Scrub to Developed, High Intensity	4 Natural to Urban
53 Shrub/Scrub to Barren Land	2 Natural
54 Shrub/Scrub to Deciduous Forest	2 Natural
57 Shrub/Scrub to Grassland/Herbaceous	2 Natural
58 Shrub/Scrub to Cultivated Crops	4 Natural to Urban
59 Shrub/Scrub to Emergent Herbaceous Wetlands	2 Natural
71 Grassland/Herbaceous to Open Water	2 Natural
72 Grassland/Herbaceous to Developed, Low Intensity	4 Natural to Urban
73 Grassland/Herbaceous to Barren Land	2 Natural

NLCD Change Class	Change Class
74 Grassland/Herbaceous to Deciduous Forest	2 Natural
75 Grassland/Herbaceous to Shrub/Scrub	2 Natural
78 Grassland/Herbaceous to Cultivated Crops	3 Natural to Agriculture
79 Grassland/Herbaceous to Emergent Herbaceous Wetlands	2 Natural
81 Cultivated Crops to Open Water	6 Converted to Natural
82 Cultivated Crops to Developed, High Intensity	5 Agriculture to Urban
83 Cultivated Crops to Barren Land	6 Converted to Natural
84 Cultivated Crops to Deciduous Forest	6 Converted to Natural
85 Cultivated Crops to Shrub/Scrub	6 Converted to Natural
87 Cultivated Crops to Grassland/Herbaceous	6 Converted to Natural
89 Cultivated Crops to Emergent Herbaceous Wetlands	6 Converted to Natural
91 Emergent Herbaceous Wetlands to Open Water	2 Natural
92 Emergent Herbaceous Wetlands to Developed, High Intensity	4 Natural to Urban
93 Woody Wetlands to Barren Land	2 Natural
94 Emergent Herbaceous Wetlands to Deciduous Forest	2 Natural
95 Emergent Herbaceous Wetlands to Shrub/Scrub	2 Natural
97 Emergent Herbaceous Wetlands to Grassland/Herbaceous	2 Natural
98 Emergent Herbaceous Wetlands to Cultivated Crops	3 Natural to Agriculture

Appendix C: NLCD impervious surface classes and reclassification scheme (NPS 2010b).

NLCD Impervious Class	Impervious Class
0% Impervious	1 0-2% Impervious
1% Impervious	1 0-2% Impervious
2-3% Impervious	2 2-4% Impervious
4-5% Impervious	3 4-6% Impervious
6-7% Impervious	4 6-8% Impervious
8-9% Impervious	5 8-10% Impervious
10-14% Impervious	6 10-15% Impervious
15-24% Impervious	7 15-25% Impervious
25-49% Impervious	8 25-50% Impervious
50-100% Impervious	9 50-100% Impervious

Appendix D: Additional Wildlife Data Considered

<u>Elk</u>

We found two primary lineages for elk habitat data in the GYA: GAP / Big Sky Institute data, and state wildlife agencies / Rocky Mountain Elk Foundation (RMEF) data. The two sources have differences in methodology and output, and while there are differences in data and methodology between each state we found the State/RMEF data to be more comprehensive in areas outside of the national parks, while the Big Sky Institute data was more complete within Yellowstone National Park.

In Idaho and Wyoming elk data was generated by the M.A.P.™ (Measure and Prioritize) Elk Habitat Project, a cooperative effort, sponsored by the Rocky Mountain Elk Foundation to produce comprehensive information about occupied North American elk habitat. Elk winter and summer range, crucial winter and summer range, parturition, migration and other important habitat areas were mapped using expert opinion of wildlife biologists. Cooperators in this project include state wildlife management agencies, federal resource management agencies such as U.S.D.A., Forest Service and U.S.D.I., Bureau of Land Management, and Tribal Nations (RMEF 2006). We considered seven categories of elk habitat data from the M.A.P.™ Elk Habitat Project:

Summer Range: The part of the overall range where 90 percent of the individuals are traditionally located between spring green-up and the first heavy snowfall. Summer range is not necessarily exclusive of winter range: in some areas summer and winter range may overlap.

Crucial Summer Range: The portion of the mid-June to mid-August summer range where elk concentrations are about double the surrounding elk densities. Areas important for lactating females, calf-rearing, antler growth and other functions requiring high quality forage and security were considered.

Winter Range: That part of the overall range where 90 percent of the individuals are located during the average five winters out of ten, from the first heavy snowfall to spring.

Crucial Winter Range: The portion of the winter range where 90 percent of the individuals are located when the annual snowpack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten.

Yearlong Range: An area used year-round by a population of elk. Individuals could be found in any part of the area at any time of the year; the area cannot be subdivided into seasonal ranges. It is most likely included within the overall range of the larger population.

In Montana, the elk data was generated by Montana Fish Wildlife and Parks (FWP) and subsequently adopted by RMEF. These data represent general species distribution. They depict species occurrence at a one square mile section level. These data are based upon 1:100,000 scale Public Land Survey Section (PLSS) boundaries, hence at a fairly broad scale and resolution appears more pixilated than corresponding data sets in Idaho and Wyoming. Data were

determined by staff biologists and experts at Montana FWP. There are two types of elk habitat in the Montana dataset:

General Distribution - Depicts areas predictably occupied by this species for part or all of its year-long range.

Winter Distribution - Depicts areas where populations of this species tend to concentrate during the winter season, commonly December through April. These areas are also considered part of the General Distribution. NOTE: Not all populations concentrate on specific ranges during the winter season. In areas where no winter distribution is delineated animals depend upon and occur across their General Distribution area during the winter season, or they may occur in localized concentrations that cannot be depicted at the scale of these maps. (Montana FWP 2008a).

Pronghorn

While uniform pronghorn habitat data is not available for the entire GYA, distributional data sets with unique purposes and methodology are available for each of the three states

Currently in Idaho, the only pronghorn habitat data in Idaho is generated by Idaho Game and Fish, and is limited to basic presence/absence distributional data used for managing hunting units. The data is not broken up into habitat types or seasonal variations. This data was originally created and released by the Interior Columbia Basin Ecosystem Management Project (ICBEMP) at 1:2,000,000 by ICBEMP staff using publications and the expert knowledge of research scientists (Idaho Fish and Game 2010).

Montana FWP provides general species distribution and depict species occurrence at a one square mile section level. These data are based upon 1:100,000 scale Public Land Survey Section (PLSS) boundaries, hence at a fairly broad scale and resolution appears more pixilated than corresponding data sets in Idaho and Wyoming. Data were determined by staff biologists and experts at Montana FWP.

Species occur in areas of suitable habitats within their overall distribution, however not all areas will have animals at all times every year. The specific areas occupied may expand or contract through time as seasons, population levels and habitat conditions change. There are two types of pronghorn habitat in the Montana dataset:

General Distribution - Depicts areas predictably occupied by this species for part or all of its year-long range.

Winter Distribution - Depicts areas where populations of this species tend to concentrate during the winter season, commonly December through April. These areas are also considered part of the General Distribution. NOTE: Not all populations concentrate on specific ranges during the winter season. In areas where no winter distribution is delineated animals depend upon and occur across their General Distribution area during the winter season, or they may occur in localized concentrations that cannot be depicted at the scale of these maps. (Montana FWP 2008b)

Wyoming pronghorn data comes from Wyoming Game and Fish and represents the 2010 pronghorn antelope seasonal range boundaries. Seasonal range delineations depict lands that are important in each season for certain biological processes within a herd unit. Seasonal range

boundaries are based on long-term observation data, specific research projects, and professional judgment. Ranges are digitized at a scale of 1:100,000 using USGS 1:100,000 DRGs as a backdrop for heads up digitizing, and are revised as needed by the Wyoming Game and Fish Department. Current seasonal range definitions are based on a 1990 document drafted by the Wyoming Chapter of The Wildlife Society in cooperation with the Wyoming Game and Fish Department and federal land agencies.

The Wyoming Game and Fish Department initially developed crucial winter ranges in the early 1960's. Herd unit boundaries and other seasonal ranges were first delineated in the early 1970's based on the knowledge of local wildlife biologists and game wardens. Tagging and radio collar studies were used to refine boundaries. Data to revise seasonal ranges comes from three sources:

1) The Wyoming Game and Fish Department's Wildlife Observation System. This database contains over a million wildlife observation records including locations, dates, and other relevant information.

2) Research data from animal movement studies performed by Wyoming Game and Fish, federal agencies, university researchers, and industry consultants.

3) Knowledge of local field personnel and land owners. Game and Fish biologists are encouraged to update seasonal range boundaries at 5-year intervals or whenever new information indicates that revisions are warranted.

There are four types of pronghorn habitat in the Wyoming dataset:

Severe Winter Relief: A documented survival range which may or may not be considered a crucial range area as defined above. It is used to a great extent, only in occasionally extremely severe winters (e.g., 2 years out of 10).

Winter: A population or portion of a population of animals use the documented suitable habitat within this range annually, in substantial numbers only during the winter (variable, but commonly between 12/1 and 4/30).

Winter/Yearlong: A population or portion of a population of animals makes general use of the documented suitable habitat within this range on a year-round basis. But during the winter months (between 12/1 and 4/30), there is a significant influx of additional animals into the area from other seasonal ranges.

Crucial: These areas can describe any particular seasonal range or habitat component (often winter or winter/yearlong range), but describes that component which has been documented as the determining factor in a population's ability to maintain itself at a certain level (theoretically at or above the population objective) over the long term.

GAP Species Data

The mission of the USGS Gap Analysis Program (GAP) is to provide state, regional and national biodiversity assessments of the conservation status of native vertebrate species and natural land cover types and to facilitate the application of this information to land management activities. Species distribution models are used to conduct a biodiversity assessment for species across the

U.S. The goal of GAP is to keep common species common by identifying species and plant communities not adequately represented in existing conservation lands. Common species are those not currently threatened with extinction. By providing these data, land managers and policy makers can make better-informed decisions when identifying priority areas for conservation.

GAP distribution models represent the areas where species are predicted to occur based on habitat associations. GAP distribution models are the spatial arrangement of environments suitable for occupation by a species. In other words, a species distribution is created using a deductive model to predict areas suitable for occupation within a species range. To represent these suitable environments, GAP compiled existing GAP data, where available, and compiled additional data where needed.

Habitat associations were based on GAP National Land Cover data of ecological systems, elevation data, hydrological characteristics, human avoidance characteristics, forest edge, and ecotone widths. Distribution models were generated using a python script that selects model variables based on literature cited information stored in a wildlife habitat relationship database (WHRdb). Distribution models are 30 meter raster data and delimited by GAP species ranges. Distribution model data were attributed with information regarding seasonal use based on GAP regional projects (SWReGAP and SEGAP), NatureServe data, and IUCN data. GAP used the best information available to create these species distribution models; however GAP seeks to improve and update these data as new information becomes available.

The purpose of the vertebrate species maps developed for gap analysis is to provide more precise information about the current distribution of individual native species within their general ranges than is generally available from published range maps. Range maps which rely only on the location of specimens do not include information on the ecological conditions that favor the presence of the species. Habitat features, such as vegetation, can enhance traditional approaches despite some limitations (Scott et al. 1993). Using both point locality records and habitat conditions, these redacted distributions provide better estimates about the actual amount of habitat area and the nature of its configuration. (USGS GAP 2007)

GAP / Big Sky Institute Species Data

The Big Sky Institute merged and vectorized original Gap data described above to highlight the distribution of Elk, Sage Grouse, Black Bear, Grizzly Bear and Bison in the GYA. (USGS GAP Big Sky Institute,
www.nbii.gov/portal/server.pt?open=512&objID=433&PageID=1594&cached=true&mode=2&userID=2)

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 960/111614, November 2011

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