Species and Habitats Most at Risk in Greater Yellowstone

By Andrew J. Hansen

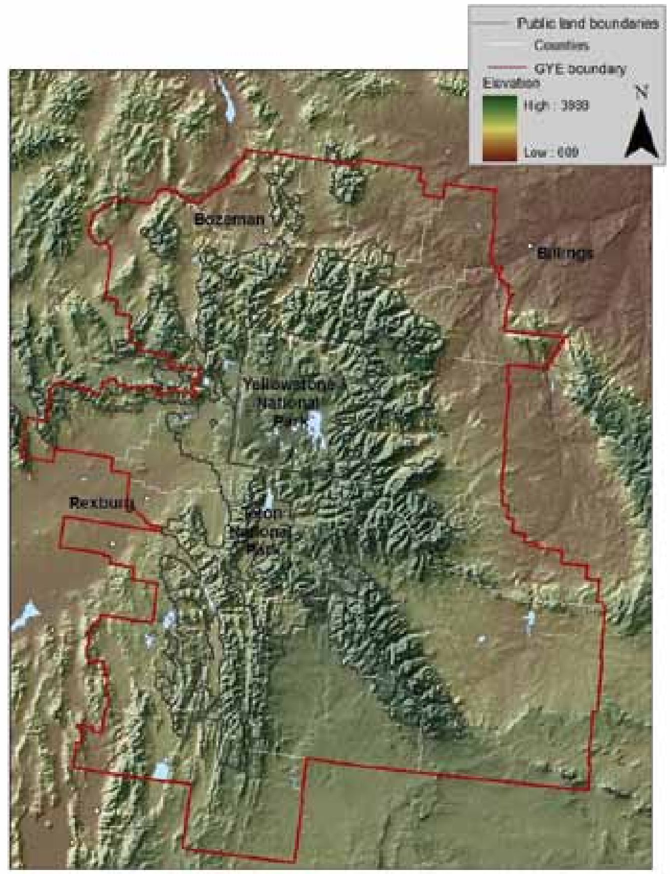

Figure 1. Map of the Greater Yellowstone Ecosystem as defined by Hansen et al. (2002).

The broad-scale ecological and human patterns of the Greater Yellowstone Ecosystem (GYE) (Fig. 1) are relatively well understood. Keiter and Boyce (1991) placed ecological processes and organisms in Yellowstone National Park in the context of the broader GYE. Glick et al. (1991) focused on the interplay between natural resources and local economics. Clark and Minta (1994) explored how government and social institutions influence management of the GYE. Hansen et al. (2002) quantified change in land cover and use in the GYE during 1975–1995 and examined the consequences for biodiversity and socioeconomics of local communities. Noss et al. (2002) rated the ecological importance of 43 "megasites" outside of protected areas based on ecological and land use factors. Gude et al. (2007) evaluated the consequences of past, present, and possible future land use on several indices of biodiversity.

These assessments and other studies have identified several successes and challenges in maintaining viable species, communities, and ecosystems across the GYE. Management of elk populations, recovery of the threatened grizzly bear, and reintroduction of wolves have involved both large, complex landscapes and extensive collaboration in research and management among federal and state agencies, private land owners, and nongovernmental organizations. The remaining challenges stem largely from the fact that GYE is a highly connected ecosystem undergoing rapid human growth and land use intensification yet composed of multiple private and public ownership types and management jurisdictions that sometimes do not correspond well to ecological boundaries. Some of the current challenges involve management of fire, the spread of weeds and disease among natural and human components of the system, and the loss of key low-elevation habitats due to rural and urban development on private lands. These changes have been vexing to managers because of the large spatial scale over which they occur and the need for coordinated management among many stakeholders. Potential emerging management issues include threats to wildlife (such as elevated grizzly bear mortality) from expanding backcountry recreation and climate-induced changes in habitat and water.

This article is drawn largely from a report that was prepared for the U.S. Forest Service (USFS) (Hansen 2006) to assess the major factors that influence species and ecosystem viability across the GYE as a context for the analysis and management of biodiversity.

Changing Land Use in the GYE

Although 64% of the GYE is publicly owned (Hansen et al. 2002), critical resources and habitats are underrepresented within the protected lands. This is because the public lands in the GYE are relatively high in elevation, harsh in climate, and low in primary productivity, whereas the private lands are primarily in valley bottoms and floodplains with longer growing seasons and higher plant productivity (Hansen et al. 2000). Consequently, hot spots for biodiversity and many ungulate winter ranges are largely on private lands (Hansen et al. 2002). The 20 counties of the GYE had 426,167 residents in 2007 (Woods and Poole Economics 2008), most living in small cities. Suburbs, agricultural lands, and rural residential homes radiate out from the cities toward the public lands. The national forests provide for multiple use of natural resources including recreation, forest products, forage, and minerals. The national parks serve both as nature reserves and as sites for public recreation.

The GYE is undergoing a transition in demography and land use. The population grew about 60% between 1970 and 1999, fueled partially by wealthy in-migrants that are attracted by the natural amenities. The dominant change in land use has been from ranching and farming to urban and exurban development (defined as 1 home per 0.4 to 16.2 hectares). Developed land has increased faster than the rate of population growth. While the GYE experienced a 58% increase in population from 1970 to 1999, the area of rural lands supporting exurban development increased 350% (Gude et al. 2006) (Fig. 2).

Some 11% of the total land area of the GYE and 43% of the private lands are subject to more intense land uses (crop agriculture, exurban, suburban, and urban) (Hansen unpublished data). Of the many miles of river flowing through private lands in the area, 89 % of the streamsides are within 1.6 kilometers (1 mile) of homes, farms, or cities. Among aspen and willow habitats, critical for wildlife, only 51% of those on private lands in the Greater Yellowstone area are more than 1.6 km from these more intense human land uses.

Major uses of the national forests include livestock grazing, logging, mining, and motorized and nonmotorized recreation. A comprehensive assessment of rates and locations of logging has not been done across the GYE. It appears that rates of logging vary among national forests and time periods. In general, large-scale commercial logging was more widespread in the 1970s and 1980s, when staggered-setting clearcutting occurred over large portions of the Targhee National Forest and in portions of the Gallatin National Forest. Less extensive timber harvesting was done on the Shoshone, Custer, and Bridger-Teton national forests. More recently, timbering operations have focused on smaller sales of house logs, fuels reductions projects, and salvage logging of burned areas. Many of the extensive road systems that were created in association with the logging have been closed by the USFS during the past decade. Livestock grazing is extensive on the national forests of the GYE. However, historical and current levels of livestock use and its effects on the ecosystem are not well known.

Some forms of public recreation have likely increased dramatically on the national forests in recent decades. Use in winter by snowmobiles and in summer by ATVs and motorcycles is extensive and increasing. Similarly, use of backcountry areas by hikers, skiers, fisherman, and campers appears to be rapidly increasing. Comprehensive data on these motorized and nonmotorized uses have not been compiled across the public lands of the GYE. However, travel management is currently receiving much attention across the region.

KARL BIRKELAND/USDA FOREST SERVICE

A backcountry skier investigates snowpack along Lionhead Ridge in Gallatin National Forest.

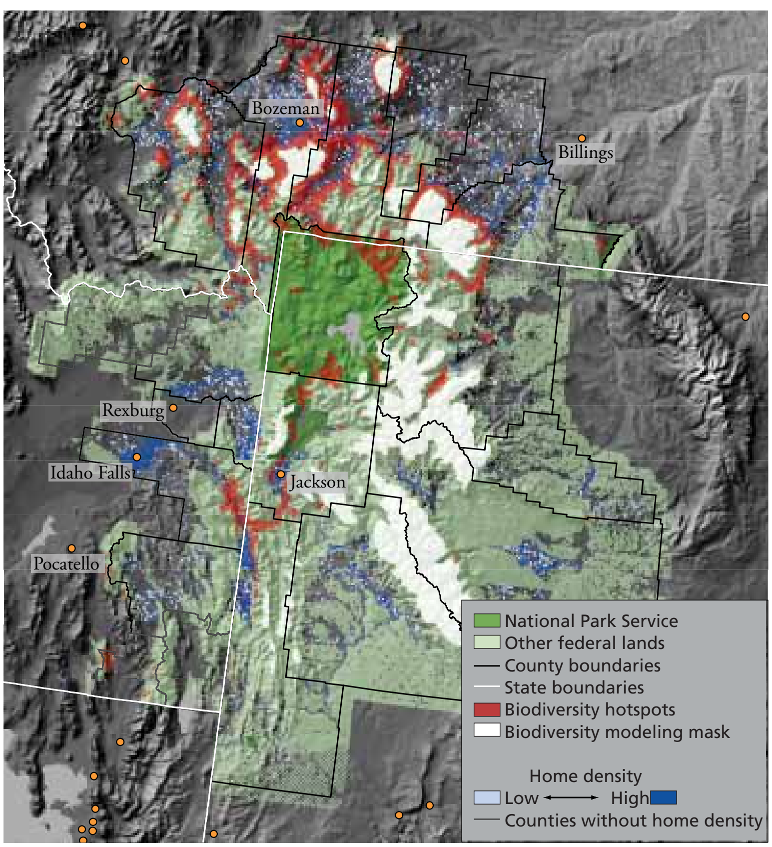

Figure 2. Distribution of rural homes across the 20 counties of the GYE in 1999. Home data were derived from county tax assessor records and validated with aerial photographs (see Gude et al. 2006). Includes biodiversity hotspots assesed by bird species presence and diversity.

Effects on Wildlife

Land use intensification exerts influences on wildlife both in and near sites of logging, agriculture, and human settlements as well as in the remaining natural parts of an ecosystem. Perhaps the most obvious repercussions are loss, fragmentation, and degradation of habitat. Conversion of natural habitats to agriculture or other intensive human land uses causes these areas to become inhospitable for many native species. Community diversity declines as habitat area is reduced. Smaller habitats can support fewer individuals within a population, hence rates of extinction increase with habitat loss. The spatial pattern of habitat also influences biodiversity potential. Habitats with small patch sizes, increased edge to area ratios, and increased distance among patches fail to support habitat interior specialists and species with poor dispersal abilities. Within forest stands, logging and other vegetation modifications may simplify the number of canopy layers and other elements of forest structure, reducing the microhabitats available to organisms and limiting biodiversity (Hunter 1999). Habitat destruction in GYE has occurred primarily in valley bottoms with more fertile soils as a consequence of agricultural and urban development (Gude 2006). Logging has fragmented forested habitats in parts of GYE (Powell and Hansen 2007) however, recovery is now underway as logging rates have dropped. While exurban development has been increasing, the area of native habitats converted to lawns, homes, and driveways is generally small relative to the remaining habitat.

Human land use can also have repercussions on ecological processes. For example, agriculture and urbanization in western Colorado have altered climate and nutrient deposition in the Colorado Rockies, with negative consequences for biodiversity in Rocky Mountain National Park. Natural processes likely altered by humans in the GYE include water quantity and quality in some rivers and streams and reduced natural disturbances such as wildfires. Irrigation leads to unnaturally low summer stream flows in some dry years with likely consequences for aquatic and riparian species. Also, water pollution levels are likely increasing in some rivers due to effluent from rural homes. Many of the rivers of the region are dammed or channelized, resulting in loss of or reduced flooding, riparian succession, and riparian habitat diversity (Merigliano 1998; Hansen et al. 2003). Fire suppression by humans in lower elevation forests has likely led thus far to reduced initiation of succession, loss of early seral habitats, and reductions in wildlife species dependent upon early seral habitats (Litell 2002). In the longer term, human fire exclusion will likely lead to unnatural fuel accumulation, and large and severe fires that may be outside the range to which native species are adapted.


JEF WITCOSKY/USDA FOREST SERVICE

Natural regeneration of *Pinus ponderosa,* ten years after a clearcut harvest in Shoshone National Forest.


NPS/PEACO

Livestock grazing, like these sheep in the Beartooth Mountains, is extensive on the national forests of the GYE.

Some of the consequences of land use change are much less visible because they involve not habitats but the organisms within habitats. Human activities often result in changed numbers and distributions of native species, as well as the introduction of alien species and pathogens. As a result, biotic interactions among species are changed, and ecosystem traits are altered. Exurban and agricultural development in the Rockies has been shown to lead to increases in mesopredators such as coyotes, skunks, and corivids and decreases in reproductive success of prey species such as neotropical migrant birds (Odell and Knight 2001). Rural development and agriculture in and near floodplains in the GYE has resulted in increased predators and brood parasites on native birds and reduced reproduction by some neotropical migrant birds which may be putting regional populations at risk (Hansen and Rotella 2002). Invasive plants are able to spread from rural homes and agricultural fields into adjacent natural habitats. The number of documented exotic plants in Yellowstone National Park has increased from 85 in 1986 to more than 200 in 2009 (GYSLC 2009), possibly due in part to human development on surrounding private lands. Also, exchange of disease among wildlife, domestic livestock

Invasive dalmation toadflax (*Linaria dalmatica*).

and pets is a growing concern in the GYE. For example, several native wildlife species contracted brucellosis, likely from domestic livestock, and are now managed to minimize risk of transmission back to livestock (Yellowstone National Park 1997). Similarly, whirling disease has been introduced to local rivers and streams, causing substantial reductions of rainbow trout populations.

Humans also interact directly with native species through exploitation and inadvertent disturbance. Domestic pets may range considerable distances from rural homes and displace and kill wildlife. Bird feeders and other food sources may attract wildlife to rural homes, leading to the need to control or destroy unwanted or dangerous wildlife. Increases in roads and vehicle usage escalate the potential for roadkill. Finally, backcountry recreation such as hiking and off-road vehicle use is increasingly popular in and around natural habitats and can displace wildlife, influencing reproduction, survival, and population dynamics. Such human activities in the GYE have led to increasing levels of grizzly bear mortality (Schwartz et al. 2007), raising concern about the viability of the population under continued human expansion and land use intensification.

Although most of these human activities are centered on private lands, Hansen and DeFries (2007) outlined four general mechanisms through which land use change on private lands may impact biodiversity on public lands (Table 1). Land use may: (1) destroy natural habitats and reduce the effective size of the larger ecosystem which can: simplify the trophic structure as species with large home ranges are extirpated; cause the area of the ecosystem to fall below that needed to maintain natural disturbance regimes; and reduce species richness due to loss of habitat area; (2) alter characteristics of the air, water, and natural disturbances moving through the public lands; (3) eliminate or isolate seasonal habitats, migration habitats, or habitats that support source populations; and (4) increase human activity along public land boundaries, resulting in the introduction of invasive species, increased hunting and poaching, and higher incidence of wildlife disturbance.

Identifying Management Priorities

Limited resources dictate that land managers focus on legal requirements, elements most important to biodiversity and ecosystem function, those most at risk due to human activities, and those at which management has the best chance of success.

Table 1. General mechanisms by which land use in surrounding areas may alter ecological processes and biodiversity within reserves. From Hansen and DeFries (2007).

Mechanism	Type	Description
Change in effective size of ecosystem	Minimum dynamic area	Temporal stability of seral stages is a function of the area of the park relative to the size of natural disturbance.
	Species area effect	As natural habitats in surrounding lands are destroyed, the functional size of the park is decreased and risk of extinction in the park is increased.
	Trophic structure	Characteristic spatial scales of organisms differ with trophic level such that organisms in higher levels are lost as ecosystems shrink.
Changes in ecological flows	Initiation and runout zones	Key ecological processes move across landscapes. “Initiation” and “run-out” zones for disturbance may lie outside the park.
	Location in airshed or watershed	Land use in upper watersheds or airsheds may alter flows into reserves lower in the watershed or airshed.
Loss of crucial habitat	Ephemeral habitats	Lands outside of parks may contain unique habitats that are required by organisms within the park.
	Dispersal/migration habitats	Organisms require corridors to disperse among parks or to migrate from parks to ephemeral habitats.
	Population source-sink habitats	Unique habitats outside of parks are population “source” areas required to maintain “sink” populations in parks.
Increased exposure to human impacts	Edge effects	Negative human influences from the park periphery extend some distance into park.

Species

Terrestrial mammal and bird species that have been identified as at risk by the USFS in the national forests of the GYE are listed in Table 2. Management to maintain the habitats and ecological processes needed by these species should help to retain many of them. Large tracts of late seral coniferous forests are required by Canada lynx, fisher, wolverine, American marten, northern goshawk, boreal owl, and three-toed woodpecker (see Table 2 for scientific names). The black-backed woodpecker is dependent upon such forests that are recently burned. Ponderosa pine with large trees and open canopies as result from frequent fire are key habitats for Lewis's woodpecker and flammulated owl. Species dependent upon riparian habitats include bald eagle, yellow-billed cuckoo, and river otter. Vigorous sagebrush habitats are required by pygmy rabbit, brewer's sparrow, burrowing owl, Columbian sharp-tailed grouse, and sage grouse. Grasslands, often in large tracts and maintained in adequate condition by fire or grazing support black-footed ferret, black-tailed prairie dog, Baird's sparrow, grasshopper sparrow, and Sprague's pipit. In contrast to these species, which are mostly dependent upon habitats and processes, both the grizzly bear and wolf are currently most limited by interactions with people and livestock. Management of animal–human conflicts may be required to maintain these species.


NPS/HARLAN KREDIT

A male three-toed woodpecker.

Habitats

Terrestrial habitats identified as most at risk in the GYE are listed in Table 3. These include habitats that are high in community diversity and energy production, and support species that specialize on these habitats, are relatively low in aerial cover in the GYE, and/or are threatened by human activities such as fire exclusion. The importance of these habitats and their vulnerabilities vary across the national forests of the GYE.

Indices of Biodiversity

Various methods are available to develop biodiversity indices that integrate across species, habitats, and other aspects of biodiversity. Two comprehensive efforts of this nature have been completed for the GYE. Noss et al. (2002) performed a

Table 2. Terrestrial mammal and bird species identified as at risk under the Endangered Species Act by the USFS in the national forests of the GYE (USDA 2004). Omitted are aquatic species and species not amenable to USFS management strategies. Threats and management strategies were derived from NatureServe (www.natureserve.org/explore/servlet/NatureServe).

Threatened, Endangered, or Candidate Species	Primary Habitat	Key Threats	Key Management Strategies
Gray wolf (*Canis lupus*)	General	Human-induced mortality	Manage human–wolf conflicts
Grizzly bear ***Ursus arctos horribilis***	General	Large home range; loss of low-elevation habitats; loss of whitebark pine; human-induced mortality	Reduce human-induced mortalities; provide low-elevation habitats; restore whitebark pine
Canada lynx ***Lynx canadensis***	Coniferous forest	Harvest; large home range; fragmentation of coniferous forest habitats; loss of diverse age structure of habitat; loss of prey; unnaturally low fire frequency	Management of roads and human access; fire management to restore habitats; minimize human harvest
Bald eagle ***Haliaeetus leucocephalus***	Riparian, costal	Recovered following pesticide effects and habitat loss	Maintain riparian and lacustrine habitats
Yellow-billed cuckoo ***Coccyzus americanus***	Riparian	Edge of range; loss of cottonwood and willow habitats	Maintain and restore riparian habitats
Black-footed ferret ***Mustella nigripes***	Prairie	Loss of prairie; loss of prey; disease	Protect current populations; captive breeding and release

Table 2 continued.

USFS Sensitive Species	Primary Habitat	Key Threats	Key Management Strategies
Fisher *Martes pennanti*	Coniferous forest	Harvest; fragmentation of old-growth coniferous forest	Maintain large tracts of old-growth forest, including low-mid elevations
North American wolverine *Gulo gulo*	Coniferous forest	Large home range; human encroachment; harvest	Maintain habitat for prey populations, including at low-mid elevations; minimize human harvest
American marten *Martes Americana origins*	Coniferous forest	Harvest; fragmentation of old-growth coniferous forest	Maintain large tracts of old-growth forest, including low-mid elevations
Northern goshawk *Accipiter gentiles*	Coniferous forest	Harvest; fragmentation of old-growth coniferous forest	Maintain large tracts of old-growth forest
Boreal owl *Aegolius funereus*	Coniferous forests	Loss of prey due to timber harvest; large home range	Maintain large tracts of suitable habitat, large snags, aspen stands
Three-toed woodpecker *Picoides tridaclylus*	Coniferous forests	Loss of older forest	Maintain older seral stages and structural complexity
Black-backed woodpecker *Picoides arcticus*	Recently burned areas, old-growth coniferous forest	Fire exclusion; timber harvest	Maintain crown fire regimes; maintain structural complexity in timber and salvage units
River otter *Lutra canadensis*	Riparian, lacustrine, coastal shores	Local trapping; loss of riparian habitat	Maintain riparian habitats
Flammulated owl *Otus flammulatus*	Ponderosa pine	Loss of large snags and forest structural complexity	Maintain large trees and structural complexity
Lewis's woodpecker *Malanerpes lewis*	Ponderosa pine, cottonwood	Loss of large snags; densification of open stands	Maintain large snags and open canopy with fire and silviculture
Black-tailed prairie dog *Cynomys ludovicianus*	Grasslands	Loss of prairie; disease	Maintain habitats
Baird's sparrow *Annodramus bairdii*	Grasslands	Loss and alteration of habitat due to agriculture and grazing	Maintain medium-height grasslands in large tracts
Grasshopper sparrow *Ammodramus savannarum*	Grassland	Loss of grassland habitats; alteration of natural fire	Maintain large tracts of grasslands; manage fire to produced relatively sparse cover
Sprague's pipit *Anthus spragueii*	Grasslands	Loss of grassland and wetland habitats	Maintain grassland and wetland habitats
Pygmy rabbit *Brachylagus idahoensis*	Shrubsteppe	Loss of shrub-steppe habitats	Protect shrubsteppe habitat, especially on floodplains
Brewer's sparrow *Spizella breweri*	Sagesteppe	Loss of sagebrush	Maintain vigorous sagebrush communities
Burrowing owl *Athene cunicularia*	Sagesteppe	Loss of sagebrush	Maintain sagebrush communities
Columbian sharp-tailed grouse *Tymphanuchus phasianellus columbianus*	Sagesteppe	Loss of sagebrush	Maintain sagebrush communities; manage grazing
Sage grouse *Centrocercus urophasianus*	Sagesteppe	Loss of sagebrush	Maintain sagebrush communities

Table 3. Habitats identified as at risk in the GYE. Aerial extent estimates from Parmenter et al. (2003) and Powell and Hansen (2007).

Habitats at Risk	Ecological Importance	Aerial Extent	Key Threats
Braided large river flood-plain s	High in species richness and net primary productivity (NPP); seral stages support specialists species	~1% of GYE	Inhibition of natural dynamics thru dams, bank stabilization, irrigation; exurban development
Other willow, cottonwood, and riparian forests	High in species richness and NPP	~1% of GYE	Flood control; dewatering through irrigation; livestock grazing; exurban development
Grasslands	Specialist species	35% of GYE (w/ sagesteppe)	Ex- and urban development; agriculture; livestock grazing; alteration of fire regime; conifer encroachment
Sagesteppe	Specialist species	35% of GYE (w/grassland)	Ex- and urban development; agriculture; livestock grazing; alteration of fire regime; exotic species; conifer encroachment
Aspen	High in species richness and NPP; several specialists species	~1% of GYE	Lack of disturbance to reduce conifer competition and stimulate aspen regeneration; excessive herbivory
Ponderosa pine	Specialists species	<1% of GYE	Alteration of fire regime; encroachment by other conifers; logging
Productive low elevation Douglas-fir forest	Moderately high in species richness and NPP	~5% of GYE	Fire exclusion leading to densification, fuel build-up, and a more severe fire regime; logging; exurban development
Early post-fire structurally complex coniferous forest	Specialist species	Highly variable*	Fire exclusion in low to mid elevations
Mature and old growth coniferous forest	Specialist species	5% of GYE	Fragmentation by logging and roads
Whitebark pine	Food source for grizzly bear	5% of GYE	Climate change; disease

*unpredictable crown fire causes high variability in aerial extent

quantitative assessment aimed at prioritizing lands outside of protected areas for conservation value. The analysis considered measures of biodiversity including imperiled species, bird species, aquatic species, and rare plant communities; vegetative, abiotic, and aquatic habitat types; and high quality habitat for five focal mammal species (wolverine, lynx, grizzly bear, gray wolf, and elk). Units of land across the GYE were rated on these measures. The SITES selection algorithm was used to assemble and compare alternative portfolios of sites. (SITES attempts to minimize portfolio "cost" in land area while maximizing attainment of conservation goals in a compact set of sites.) The sites were evaluated for irreplaceability (a quantitative measure of the relative contribution different areas make to reaching conservation goals) and vulnerability (based on expert opinion with data on human population growth and land use). Of the 43 sites that best fulfilled the conservation objectives; 15 were identified as of greatest importance because they rated high in both irreplaceability and vulnerability. The Teton River Area near Jackson, Wyoming, and Henry's Fork near Island Park, Idaho, had the highest scores. The resulting maps of the sites (Figure E10 in Noss et al. 2002) and tables of scores for irreplaceability and vulnerability offer guidance to land managers on locations of high conservation value.

The second assessment (Gude et al. 2007) focused on the geographic overlap of biodiversity value and land use intensity in the past, present, and possible future. Historical land use maps were overlain on 11 biodiversity response variables: the current ranges of four species of concern (grizzly bear, elk, pronghorn antelope, and moose); the distribution of four land cover types (Douglas-fir, grassland, aspen, and riparian); and the occurrence of three biodiversity indices (bird hotspots, mammal migration corridors, and irreplaceable areas, from Noss et al. 2002). They found that exurban densities of rural homes occurred at higher proportions within most of these habitats than would be expected at random, indicating that these responses are at high risk to the negative impacts of development. Additionally, they integrated maps from 1980 and discovered that the percent area of currently occupied habitat that is impacted by homes has at least

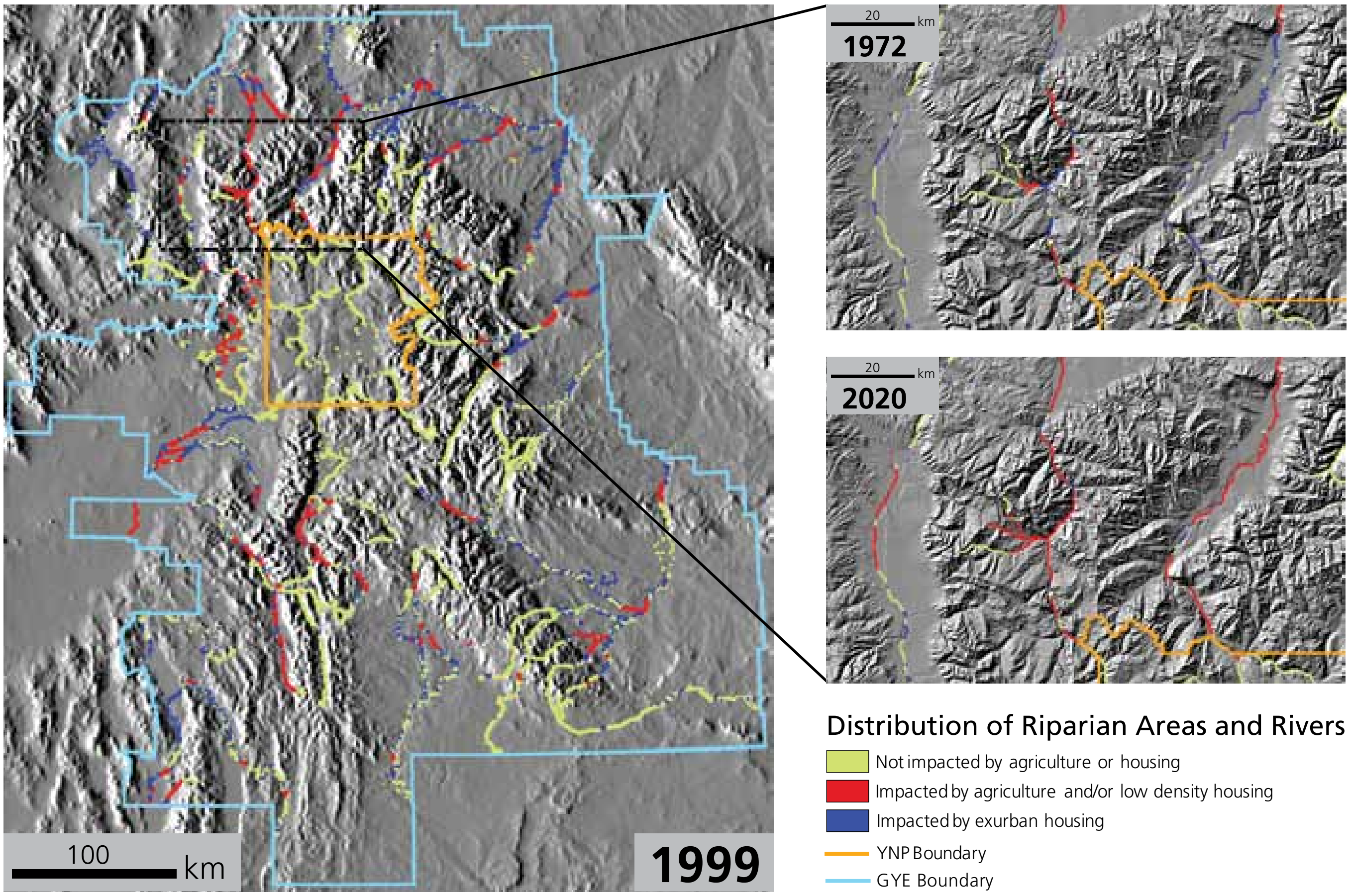

Figure 3. The distribution of riparian areas and rivers across the GYE and the extent of overlap with agricultural and exurban land uses (within 1.6 kilometers) in 1999, for 1972 and projected for 2020 assuming that the same growth rates from the 1990s continue into the future.

doubled for most variables over the past 20 years.

Based on these historical and current analyses of land use, Gude et al. (2007) projected rural home growth 20 years into the future and quantified potential impacts on biodiversity. They simulated five plausible scenarios of rural residential development for the year 2020. These scenarios ranged from low growth, to status quo (current rates of growth continue), to booming growth, and included two scenarios depicting development under growth management. These five maps depicting potential future land use scenarios were then each overlaid with each of the 11 ecological response maps used for historical analyses. Numbers of rural homes increased for all scenarios, ranging from 28% in the low growth scenario to 234% in the boom scenario. Four of the responses (bird hotspots, riparian habitat (Figure 3), potential corridors, and irreplaceable areas; were forecasted to experience degradation in at least 20% of their area under the status quo and 30–40% under the boom scenario (Table 4). These elements of biodiversity should be considered especially at risk across the GYE. Early warning of the vulnerability of these four habitats to land use change may help managers to develop strategies for mitigating future effects.

Climate Change

Climate change presents an especially difficult challenge to land managers. Because the effects of human-induced climate change occur over longer periods of time than those of land use change, management to adapt to climate change is often considered a lower priority. However, natural variability combined with climate change can bring extreme weather that leads to ecological outcomes expected under climate change and requires management action. The extreme fires in the West under the drought conditions of the last five years are an example. Climate change interacts with land use change in ways that challenge management. For example, fragmentation due to land use reduces connectivity of habitats that is essential to species shifting range under changing climate. Finally, there is considerable uncertainty in our ability to predict the form and outcome of human-induced climate change, which reduces public support to manage for its consequences.

As climate change is more fully manifest, active management will be increasingly needed to maintain ecological function and native species (Hansen et al. 2001). For plant communities that are unlikely to reach suitable environments

Table 4. The percent of area impacted by exurban development is presented for each of 11 biodiversity response variables. The impacts of exurban development were assumed to extend into one neighboring section (1.61km). Table adapted from Gude et al. (2007).

			Growth Scenario			Growth Management Type	
Response	1980	1999	Status Quo 2020*	Low 2020	Boom 2020	Moderate 2020	Aggressive 2020
Pronghorn Range	2.00%	3.35%	5.83%	5.05%	7.58%	6.06%	4.73%
Moose Range	2.73%	5.49%	7.96%	6.83%	11.11%	7.24%	6.26%
Grasslands	2.99%	5.57%	8.36%	7.02%	11.97%	8.01%	6.87%
Grizzly Bear Range	3.13%	5.98%	8.52%	7.68%	10.70%	7.74%	6.88%
Douglas-fir	2.91%	6.01%	8.85%	7.07%	13.31%	7.82%	7.09%
Elk Winter Range	2.36%	6.26%	9.98%	8.61%	13.47%	9.00%	7.23%
Aspen	5.55%	13.92%	19.53%	15.58%	28.39%	18.74%	17.60%
Bird Hotspots	8.42%	16.91%	23.20%	19.23%	34.36%	21.04%	20.23%
Riparian Habitat	10.22%	17.30%	23.64%	19.43%	31.27%	22.45%	18.77%
Potential Corridors	8.89%	18.79%	24.43%	20.83%	35.38%	22.96%	21.80%
Irreplaceable Areas[1]	11.41%	23.15%	29.61%	25.69%	40.08%	30.88%	26.92%
Integrated Index[2]	11.80%	23.24%	29.93%	25.84%	40.66%	29.28%	26.43%

* Responses are ranked by the proportion impacted in the Status Quo 2020 scenario

[1] Multicriteria assessment based on habitat and population data for GYE species (Noss et al., 2002)

[2] Top 25% of lands important to the four responses most impacted by development under the Status Quo 2020 scenario, including bird hotspots, riparian habitat, potential corridors, and irreplaceable areas.

elsewhere (e.g., subalpine and alpine communities), it may be appropriate to minimize change by manipulating vegetation structure, composition, and/or disturbance regimes to favor the current community. For communities that may be able to reach newly suitable habitats, a reasonable strategy may be to manage some of the current habitat as a reservoir until the community is reestablished in the new locations. Other portions of the current habitat may be managed to encourage change to the species and communities more appropriate for the new environment. Attempting to maintain connectivity among natural habitats is also important for allowing natural dispersal of organisms.

Guidelines for Managing for Biodiversity

This review indicates that the GYE is a complex ecosystem that includes many ecological processes and organisms operating over very large spatial scales and that is undergoing rapid change in climate and land use. Consequently, ecological management presents numerous challenges. Fortunately, the ecosystem has been less altered by human activities than have most areas of the United States and the opportunity remains to sustain ecological processes and native organisms under future global change. The following guidelines are aimed at aiding the management of biodiversity across the GYE.

Biodiversity goals on public lands will best be advanced through land management agencies participating in management at multiple spatial scales, i.e., within federal jurisdictions (e.g., a national forest), among public land jurisdictons of the GYE, and across the public and private lands of the GYE. At the regional scale, public officials can help private land managers understand ecological connections, prioritize important places, and implement criteria for maintaining biodiversity across the GYE in the face of land use

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Island Lake in Wyoming's Wind River mountains on the Bridger-Teton National Forest.

intensification. These efforts should be guided through a scientific assessment of the lands across the GYE that are most important for the maintenance of native biodiversity on public lands.

Human induced climate change will increasingly influence national forests and require management attention. In the coming decade, land managers should conduct their activities in the context of a changing climate, recognizing that current and future forest dynamics will likely differ from the past. In the longer term, ecological engineering may be required to maintain ecological values in the face of substantial climate change.

Careful management of disturbances such as fire, flooding, and timber harvest is needed to maintain the full suite of seral stages and structural complexities across the GYE. In the face of climate and land use change, managers should apply disturbance so as to achieve the dynamic steady state mosaic across the landscape that is required to maintain native organisms. This effort would be advanced through compilation of the wildlife species associated with each seral stage and structural configuration across the habitat types of the GYE and the landscape configuration of seral stages that best promotes maintenance of native species. Also, restoration of habitats now at risk due to lack of disturbance should be a high priority.

More scientific approaches are needed for effective management of recreation on national forests. Data systems are needed to monitor recreation type and intensity in a spatially explicit manner. Research is needed on the effects of various types and intensities of recreation on biodiversity.

Changes in and trophic structure can cascade through ecosystems resulting in loss of some native species and alteration of ecosystem function. Land managers can help maintain balanced wildlife communities by maintaining habitat for top carnivores, managing campgrounds and feed lots to reduce food provisioning to mesocarnivores, and controlling noxious weeds.

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