National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Bighorn Canyon National Recreation Area

Natural Resource Condition Assessment

Natural Resource Report NPS/BICA/NRR—2012/554

ON THE COVER
Reflections on Bighorn Lake
Photograph by: Henthorne, NPS

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Executive Summary

An Act of Congress established Bighorn Canyon National Recreation Area (BICA) on 15 October 1966, following the construction of the Yellowtail Dam along the Bighorn River. The Yellowtail Dam - a multi-purpose development providing irrigation water, flood control, power generation, and recreational opportunities - is the culmination of many years of irrigation and flood control in the Bighorn Basin. The purpose of the recreation area, as stated in its enabling legislation, is to "provide for public outdoor recreation use and enjoyment of Yellowtail Reservoir and lands adjacent thereto and for the preservation of the scenic, scientific and historic features contributing to public enjoyment of such lands and waters" (16 U.S.C. § 460t [a]).

In 2003, the National Park Service Water Resources Division received funding through the Natural Resource Challenge program to systematically assess watershed resource conditions in NPS units, establishing the Watershed Condition Assessment Program. This program, now titled the Natural Resource Condition Assessment (NRCA) Program, aims to provide documentation about the current conditions of important park resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA, including the report and accompanying map products, will help BICA managers to

- develop near-term management priorities,
- engage in watershed or landscape scale partnership and education efforts,
- conduct park planning (e.g., Resource Stewardship Strategy),
- report program performance (e.g., Department of the Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

Specific project expectations and outcomes for the BICA NRCA are listed in Chapter 3.

For the purpose of this NRCA, NPS staff identified key resources that are referred to as components in the project framework and throughout the assessment. The components selected include natural resources and processes that are currently of the greatest concern to park management at BICA. The final project framework contains 17 resource components, along with measures, stressors, and reference conditions for each.

This study involved reviewing existing literature and data for each of the components in the framework, and, where appropriate, analyzing the data in order to provide summaries or to create new spatial or statistical representations. After gathering data regarding current condition of component measures, those data were compared to reference conditions, when possible, and a qualitative statement of condition was developed. The discussions in Chapter 4 represent a comprehensive summary of available information regarding the current condition of these resources. These discussions represent not only the most current published literature, but also unpublished park information and, most importantly, the perspectives of resource experts, both NPS and non-NPS.

Overall, for resources that have enough associated data and literature to define condition, condition is generally of low concern. Some resources that exhibited condition of higher concern (cottonwood-dominated woodlands and wild horses) are largely beyond the control of NPS. For all components that directly relate to the park's purpose of providing recreational opportunity, the condition is of low concern. Given the complications of multi-agency management at BICA, the good condition of the resources reflects the deliberate collaboration between agencies and citizen stakeholders.

Acronyms and Abbreviations

BICA - Bighorn Canyon National Recreation Area

BLM - Bureau of Land Managment

BOR - Bureau of Reclamation

EPA - Environmental Protection Agency

EPMT- Exotic Plant Management Team

GRYN - Greater Yellowstone Network

GYSLC - Greater Yellowstone Science Learning Center

I&M - Inventory and Monitoring

MTFWP - Montana Fish, Wildlife, and Parks

MTNHP - Montana Natural Heritage Program

NOAA - National Oceanic and Atmospheric Administration

NPS - National Park Service

NRCA - Natural Resource Condition Assessment

NRCS - Natural Resource Conservation Service

PMWHR - Pryor Mountain Wild Horse Range

SMUMN GSS - Saint Mary's University of Minnesota GeoSpatial Services

USACE – United States Army Corps of Engineers

USFS - United Stated Forest Service

USFWS – United States Fish and Wildlife Service

USGS - United States Geological Survey

WG&F - Wyoming Game and Fish

YWHMA - Yellowtail Wildlife Habitat Management Area

Chapter 1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks". For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the things identified on a list of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, not replace, traditional issue and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

> ***NRCAs Strive to Provide…***
>
> *Credible condition reporting for a subset of important park natural resources and indicators*
>
> *Useful condition summaries by broader resource categories or topics, and by park areas*

- are multi-disciplinary in scope[1]
- employ hierarchical indicator frameworks[2]
- identify or develop logical reference
- conditions/values to compare current condition data against[3,4]
- emphasize spatial evaluation of conditions and GIS (map) products[5]
- summarize key findings by park areas[6]
- follow national NRCA guidelines and standards for study design and reporting products

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current

[1] However, the breadth of natural resources and number/type of indicators evaluated will vary by park

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition reporting by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions

[4] Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers")

[5] As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products

[6] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on a area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested

park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park's boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is also important: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for some of a park's "Vital Signs" monitoring indicators. They can also bring in relevant non-NPS data to help evaluate current conditions for those same Vital Signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change effects on park natural resources is outside the project scope.

However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource

Important NRCA Success Factors …

Obtaining good input from park and other NPS subjective matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ➪ indicators ➪ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings planning[1] and help parks report to government accountability measures[2].

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in our present data and knowledge bases across these varied study components.

NRCAs can yield new insights about current park resource conditions but in many cases their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA Program information is posted at: http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm.

NRCA Reporting Products…
Provide a credible snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations
(near-term operational planning and management)
Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values
(longer-term strategic planning)
Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public
("resource condition status" reporting)

[1] NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy(RSS) but study scope can be tailored to also work well as a post-RSS project
[2] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget

Chapter 2 Introduction and Resource Setting

2.1 Park History and Enabling Legislation

Bighorn Canyon National Recreation Area (BICA) is an area rich with history. The water, natural resources, and geographic location of the Bighorn Basin have attracted humans for centuries. The Bad Pass trail, which follows the Bighorn River, was a natural corridor for travel and trade and has been part of a regional complex trail system since at least 8,500 years before present (GYSLC 2008a). The Crow Indians migrated to the area in the early 1700s and still live in the area (GYSLC 2008a). In the 1860s gold was discovered in Montana, bringing an influx of miners. Fort C.F. Smith was built by the United States military to protect miners and other travelers following the Bozeman trail from Native Americans. The Crow Indian Reservation was established by the treaty of 1851.

Cattle ranching reached Bighorn Basin in 1879 (GYSLC 2008a). Many farmers came into the surrounding area under the Homestead Act of 1862, which encouraged the establishment of 65 hectare (160-acre) farms west of the Mississippi River. Before long, permanent settlements appeared near perennial water sources at Lockhart, Hillsboro, Sorenson, and Mason-Lovell ranches in Bighorn Canyon where they diverted springs and streams for crop development and to provide water for animal husbandry.

An Act of Congress established Bighorn Canyon National Recreation Area (BICA) on 15 October 1966, following the construction of the Yellowtail Dam along the Bighorn River. The Yellowtail Dam - a multi-purpose development providing irrigation water, flood control, power generation, and recreational opportunities - is the culmination of many years of irrigation and flood control in the Bighorn Basin. The purpose of the recreation area, as stated in its enabling legislation, is to "provide for public outdoor recreation use and enjoyment of Yellowtail Reservoir and lands adjacent thereto and for the preservation of the scenic, scientific and historic features contributing to public enjoyment of such lands and waters" (16 U.S.C. § 460t (a) (NPS 2000).

2.2 Park Significance

Several features of the park have local and national significance. The deep canyons of the Bighorn River and the confluence of the Bighorn with the Shoshone River are significant for their important plant and animal habitats and outstanding scenic and recreational values.

Much of Bighorn Canyon is narrow and confined with sheer walls as high as 335 meters (1,000 feet) and similarly deep side canyons occur intermittently throughout the park. The steep canyon walls provide habitat for peregrine falcon (*Falco peregrinus*) and are a significant scenic resource of Bighorn Canyon (NPS 1981).

Bighorn Lake, at 1,115 meters (3657 feet) elevation, encompasses 7,001 surface hectares (17,300 acres) and is an important recreational destination area (NPS 2000); common recreational activities include fishing, boating, and wildlife viewing. The lake impounds more than 1,328,360 cubic feet of water (BOR 2012) and is a significant water resource (Jacobs et al. 1996) because it provides irrigation water, flood control, and power generation.

Spaniards reintroduced horses to North America in the 1500s. Trade with Native Americans, ranchers, and missions helped spread the species throughout the continent. The horses of the Pryor Mountain Wild Horse Range (PMWHR) are descendants of domestic horses introduced by Spaniards and more recently escaped or abandoned domestic horses. It is unknown when horses first appeared in the Pryor Mountains or where they came from, but the population almost certainly has a Spanish origin (Cothran 1992, as cited in GYSLC 2008). The Pryor Mountain horses are the subject of great public interest and are a draw for tourism in the area.

The diverse habitats at the confluence of the Bighorn and Shoshone Rivers in the Yellowtail Wildlife Habitat Management Area (YWHMA) are also significant resources in the park. The area includes one of the largest remaining old-growth cottonwood riparian systems in Wyoming and has the most extensive bat foraging habitat in the Greater Yellowstone Area (Keinath 2005b). The Audubon Society (2012) identified the YWHMA as an Important Bird Area because of its ornithological significance and the area is one of the premier upland game and pheasant hunting areas in the state. The Wyoming Game and Fish Department identified this area and the Lower Bighorn River Complex as a crucial habitat area in that the river provides habitat including high water refuge, spawning and nursery habitat for 20 native cool/warm water fish species including a productive sport fishery, and nine native fish species in the status 1-3 category (WG&F 2009).

The Montana Fish, Wildlife, and Parks (MTFWP) considers the Bighorn River downstream from the Yellowtail Afterbay Dam, to be one of the world's finest trout streams because of its abundant trout, dense insect hatches, and easy access (MTFWP 2010). The river's silt load is trapped behind the reservoir dam and the river below is a cold, clear tailwater, much like a giant spring creek and is an ideal habitat for trout.

Over 35 springs, many that are perennial, are located in in the park. The Water Resource Management Plan (Jacobs et al. 1996) identified ground water and associated seeps and springs that maintain riparian and aquatic habitats and provide water supply as an exceptional water resource.

Many of the park's historical properties are on the National Register of Historic Places, including Bad Pass Trail; Pretty Creek Archeological site; Lockhart, Hillsboro, Sorenson, and Mason-Lovell ranches; and the Bighorn Canal Headgate. Nearby sites just outside the park boundary include Sykes Cabin, Sykes Graves, Dry Head Siege Site, Hayfield Battle Site, Fort Smith, the Bozeman Trail, and Stuart Fight Site. Twelve basic types of archeological sites exist in Bighorn Canyon: tipi ring sites, wooden structures, caves and rockshelters, buffalo jumps, burials, quarries, rock art sites, vision quest sites, a medicine wheel site, and cairns/rock alignments.

2.3 Geographic Setting, Climate and Biota

Geographic Setting

The Bighorn Canyon National Recreation Area straddles the Wyoming-Montana border and is more than 48,562 hectares (120,000 acres) in size (Plate 1). The Crow Reservation extends north and east of the park and constitutes nearly half of the land within the boundaries of the park, although the NPS does not manage Crow lands. The landscape of the park and surrounding area is attributed to a framework of uplifts and sedimentary basins. Elevations within the park range from 975 meters (3,200 feet) to 2,134 meters (7,000 feet).

Two major rivers – the Shoshone and Bighorn – flow within Bighorn Canyon (Plate 2). The Bighorn River is a tributary to the Yellowstone River and flows from the Wyoming Basin and Bighorn Mountains northward into the Northwestern Great Plains in south-central Montana (KellerLynn 2011). The Shoshone River originates in Yellowstone National Park and is the largest tributary of the Bighorn River. The two rivers converge in southern BICA.

Bighorn Lake is about 116 kilometers (72 miles) long at full pool elevation and was created by the Yellowtail Dam in 1966. Much of the lake is within a narrow canyon and is by far the most prominent feature within the park boundaries (Jacobs et al. 1996). A second dam, the Yellowtail Afterbay Dam, is located 3.6 kilometers (2.2 miles) downstream of the Yellowtail Dam. Yellowtail Afterbay Dam provides a uniform daily flow into the Bighorn River and levels the peaking power discharges from Yellowtail Power Plant.

The park consists of two districts, one in the south and one in the north. South district headquarters is located at Lovell in Big Horn County, WY which has a population of 11,688 residents (U.S. Census Bureau 2010). Lovell is a rural town with a population of 2,281 in 2000 (U.S. Census Bureau 2000). Park headquarters is located at Fort Smith, Big Horn County, MT which has a population of 12,865 residents (U.S. Census Bureau 2010). Fort Smith had a population of 122 in 2000 (U.S. Census Bureau 2000).

Geomorphology and Geology
The Bighorn Basin is a structural basin bounded on the west by the Absaroka Range and Beartooth Mountains, on the south by the Owl Creek Mountains and to the east and northwest by the Bighorn and Pryor Mountains (Zelt et al. 1999). Although distinct, the Bighorn and Pryor Mountains form the northwest extension of the Bighorn structural uplift.

The Bighorn Canyon was formed by a combination of accelerated stream erosion and geologic uplifting 10-12 million years ago. The canyon and surrounding landforms expose the most prominent rocks including Mississippian-age Madison Group, which make up the walls of Bighorn Canyon. The Triassic-age Chugwater Formation is also visually prominent (KellerLynn 2011).

Climate
The climate of Bighorn Canyon is continental and characterized by cold winters and hot summers. The park's geographic location results in precipitation patterns unique to the area and the distribution of precipitation is locally affected by the Bighorn and Pryor Mountains which receive a higher proportion of precipitation, much of it as snow, and create a rain shadow effect at lower elevations.

The south district of Bighorn Canyon tends to be colder and drier than the north district based on climate records collected by the NOAA Cooperative Observation Network at Lovell (station 485770) and at Yellowtail Dam (station 249240). The mean annual (1981-2010) maximum and minimum temperatures reported at Lovell are 14.6°C and -0.3°C (58.20°F and 31.51°F), whereas the annual mean maximum and minimum temperatures reported at Yellowtail Dam are 16.2°C and 2.7°C (61.2°F and 36.8°F), respectively. Mean annual (1981-2010) temperatures range from

7.1°C (44.8°F) at Lovell near the south end of BICA to 9.4°C (49°F) at Yellowtail Dam at the north end of BICA in Montana (NCDC 2011).

Annual temperature extremes range from about -41.1°C (-42°F) during the winter (January 1924 at Lovell) to 42.8°C (109°F) during the summer (July 2002 at Yellowtail Dam). Temperatures generally are coldest in January when the average (1981-2010) daily minimum temperatures range from 13.7°C (7.4°F) at Lovell to -7.1°C (19.2°F) at Yellowtail Dam. July is normally the warmest month, with average (1981-2010) daily highs ranging from about 30°C (86°F) at Lovell to about 31.1°C (88°F) at Yellowtail Dam. The average frost-free period ranges from 18.1 weeks at Lovell based on the 1897-2010 average, to 21.4 weeks at Yellowtail Dam based on the 1948-2010 average.

Yellowtail Dam normally receives 2.5 times the annual precipitation compared to Lovell. The 30-year (1971-2000) average annual precipitation ranges from 16.89 cm (6.65 in.) at Lovell to 45.29 cm (17.83 in.) at Yellowtail Dam. Springtime is peak precipitation months in both places and the months of April–June accounted for 45% of the average annual precipitation at Lovell and 42% of the average annual precipitation at Yellowtail Dam in 2010 (Jean et al. 2011).

The main canyon and the various side canyons experience both upslope and downslope winds due to differential heating in the canyons, allowing for a mixing of air. The general wind direction is northwest with occasional winter winds from the southeast. The air is generally free flowing except in the summer when a high-pressure ridge may build up over the area or in the winter with inversions causing stagnant air due to extreme cold temperatures. Winds tend to be stronger in winter due to Arctic fronts passing through (NPS 2009).

Estimates of paleoclimate conditions for the northern Bighorn Basin were obtained by Lyford et al. (2002) who used plant macrofossil and pollen analyses of 55 ^{14}C- dated woodrat middens to describe late Quaternary vegetation and climate change. The authors estimate that during the early Holocene period, some 10,000 – 82,000 ^{14}C B.P., the climate was cool and moist compared to present climate. Increased aridity during the middle Holocene (7,600 – 5,500 ^{14}C B.P.) promoted a shift from boreal to Great Basin. With the exception of a late Holocene wet phase, the plant macrofossil and pollen analyses from the middle and late Holocene periods show in**c**reased aridity (Lyford et al. 2002) during this period.

Hydrologic Setting

The Bighorn River Basin above Yellowtail Dam is part of the Upper Missouri River Basin (Plate 3); the Bighorn River itself flows into the Yellowstone River downstream from Billings, Montana. Several minor tributaries flowing into the river inside the park originate from the Pryor Mountains to the west and the Bighorn Mountains to the east. BICA includes portions of the Bighorn Lake, Shoshone, and Lower Bighorn 4th level Hydrologic Units or sub-basins (Plate 3): The Bighorn Lake sub-basin (Hydrologic Unit Code (HUC) no. 10080010) has an area of 4,662 square kilometers (1,800 square miles), and includes Bighorn Lake, and the Bighorn River and its eastern tributaries upstream from Fort Smith, Montana. The lake has a storage capacity of 1.3 x 106 acre-feet, and a surface area of 7,001 hectares (17,300 acres). The average residence time for water in Bighorn Lake is approximately 6 months (Woods and Corbin 2003).

The Bighorn River has a drainage area of 40,823 square kilometers (15,762 square miles) at the United States Geological Survey (USGS) gage located approximately 0.8 kilometers (0.5 miles) upstream from where it flows into Bighorn Lake (USGS gage no. 06279500, Bighorn River at Kane, Wyoming). The mean annual discharge of the Bighorn River at this gage is 2,250 cubic feet per second (cfs) and the mean annual peak flow is 12,300 cfs (Woods and Corbin 2003).

The Shoshone sub-basin (HUC no. 10080014) has an area of 3,859 square kilometers (1,490 square miles) and includes the Shoshone River and its tributaries from its headwaters to where it flows into Bighorn Lake. The Shoshone River has a drainage area of 7,741 square kilometers (2,989 square miles) at the USGS gage upstream from where it flows into Bighorn Lake (USGS gage no. 06286200, Shoshone River at Kane, Wyoming). The mean annual discharge of the Shoshone River at this gage is 1,150 cfs and the mean annual peak flow is 7,600 cfs (Woods and Corbin 2003).

The Lower Bighorn sub-basin (HUC no. 10080015) has an area of 5,128 square kilometers (1,980 square miles), and includes all of the tributaries of the Bighorn River between Fort Smith and the confluence with the Yellowstone River at Bighorn, Montana, a distance of about 65 miles. The Bighorn River has a drainage area of 59,272 square kilometers (22,885 square miles). At the confluence with the Yellowstone River, the river has a mean annual discharge of 3,950 cfs and a mean annual peak flow of 15,700 cfs (Woods and Corbin 2003).

Flora and Fauna

Bighorn Canyon is home to more than a thousand vascular plant and vertebrate species; 87% are native to the area. An inventory of plants and animals by the NPS I&M program recorded and certified 56 mammals, of which 9% are non-native species; 224 bird species, of which 4.5% are non-native species; five amphibian and ten reptile species (all native); 35 fish, of which 3.7% are non-native species; and 741 vascular plant species, of which 15% are non-native species; as present in the park (NPS 2012).

Two iconic species, bighorn sheep (*Ovis canadensis*) and non-native wild horse (*Equus caballus*) are common in the south district of the park. Other ungulates include mule deer (*Odocoileus hemionus*) and pronghorn (*Antilocapra americana*). Carnivore species include mountain lion (*Puma concolor*), bobcat (*Lynx rufus*), coyote (*Canis latrans*) and black bear (*Ursus americanus*) (Keinath 2005a). Keinath (2005b) found that Bighorn Canyon had the richest and most concentrated bat fauna of the three parks in the Greater Yellowstone Network (GRYN), despite representing less than two percent of the area within the Network. Layout Creek and its unique mix of habitat features, in particular the small pond next to the Ewing-Snell Ranch, was the richest location inventoried with 13 species of bats documented there. The YWHMA provides ideal foraging habitat for many bat species and is probably the most productive area in the GRYN. Of the bat species reported in Bighorn Canyon, the little brown bat (*Myotis lucifugus*) and big brown bat (*Eptesicus fuscus*) are the most common, occurring at high abundance. Both species tend to roost in buildings, but they also use rock crevices, caves, abandoned mines, bridges, and tree cavities.

The geological features in Bighorn Canyon are ideal for the formation of cliff roosting habitat good for the pallid bat (*Antrozous pallidus*) and Townsend's big-eared bat (*Corynorhinus townsendii*). The most critical and restrictive feature of Townsend's big-eared bat ecology is the requirement for large cavern-like structures for roosting during all stages of its life cycle. Maternity roosts are even more limiting, as they must be consistently warm throughout the breeding season. There are several known maternity colonies near Bighorn Canyon.

Among the 246 bird species found in the park are the peregrine falcon (*Falco peregrinus*), and bald eagle (*Haliaeetus leucocephalus*), both of which have been delisted as threatened from U.S. Fish and Wildlife Service but are still considered sensitive by the U.S. Forest Service and Bureau of Land Management (MTNHP 2012) and the olive-sided flycatcher (*Contopus borealis*) which is on the Audubon Society's watch list (NAS 2007) due to its precipitous population declines in nearly every region of its breeding range. Game species are or were once stocked in the YWHMA include ring-necked pheasant (*Phasianus colchicus*) and wild turkey (*Meleagris gallopavo)*, Chukar (*Alectoris chukar*), and gray partridge (*Perdix perdix*).

Amphibian species such as the northern leopard frog (*Rana pipiens)* that have undergone significant declines in parts of Wyoming and Montana have a limited distribution in Bighorn Canyon, but are common at sites where they do occur (Baum and Peterson 2005). Wetlands and riparian areas associated with rivers and streams in the YWHMA are the most important habitats in the park for amphibians (Redder et al. 1986, Baum and Peterson 2005). Baum and Peterson (2005) encountered Woodhouse's toads (*Anaxyrus woodhousii*) at the highest number of wetland sites where they were common along with boreal chorus frogs (*Pseudacris maculata*) and northern leopard frogs. The plains spadefoot toad *(Spea bombrifrons)* which is listed by the Montana Natural Heritage Program (MTNHP 2012) as a species of concern, are uncommon in the park (Baum and Peterson 2005).

Reptile species include the western rattlesnake (*Crotalus viridis*), painted turtle (*Chrysemys picta*), spiny softshell (*Apolone spinifera*), greater short-horned lizard (*Phrynosoma hernandesi*), and common sagebrush lizard (*Sceloporus graciosus*) (Baum and Peterson 2005).

The Bighorn River and its tributaries support warm and cold-water fisheries. Warm-water native species include channel catfish (*Ictalurus punctatus*), sauger (*Sander canadensis)*, sturgeon chub (*Macrhybopsis gelida*), white sucker (*Catostomus commersoni*), and flathead minnow (*Pimephales promelas*). Fish species are stocked in some of the Wyoming tributaries of Bighorn Lake and in the lake itself. Game species in Bighorn Lake include walleye (*Sander vitreus*), yellow perch (*Perca flavescens*), and smallmouth bass (*Micropterus dolomieu*).

Cold-water species include the native longnose sucker (*Catostomus catostomus*) and non-native trout. A nationally popular trout fishery exists for rainbow trout *(Oncorhynchus mykiss)* and brown trout *(Salmo trutta)* on the Bighorn River downstream of the Yellowtail Afterbay.

Knight et al. (1987) classified the six most common vegetation types in Bighorn Canyon. They include juniper and curlleaf mountain mahogany woodlands (40%); riparian vegetation (16%); desert shrubland (15%); sagebrush steppe (12%); grasslands (8%) and coniferous woodlands (6%).

The vegetation diversity at Bighorn Canyon is partly due to the abrupt changes in topography and geologic features and the position of the park in the arid Bighorn Basin and western edge of the more humid Great Plains (Knight et al. 1987). The elevation gradient spans 1,509 meters (4,950 feet) from the reservoir to the top of East Pryor Mountain.

Three well-represented floristic elements describe the broad vegetation patterns in the park. The Great Basin element is most common in the southern end of the park and include greasewood (*Sarcobatus vermiculatus*), four-wing salt bush (*Atriplex canescens* var. *canescens*), curl-leaf mountain-mahogany (*Cercocarpus ledifolius* var. *ledifolius*), and Utah juniper (*Juniperus osteosperma*). A migration route enabled Utah juniper to migrate from Nevada and Utah northward through the Bighorn Basin (Kratz 1988, as cited in McCarthy 1996). The Utah juniper at Frozen Leg is the northernmost extension of this species (NPS 1981).

The Great Plains element is more common in the northern part of the park and is represented by side-oats grama (*Bouteloua curtipendula*), little bluestem (*Schizachyrium scoparium*) and other prairie forb species. The Rocky Mountain floristic element is common in the higher elevations and towards the northern end with species such as subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmannii*), Douglas–fir (*Pseudotsuga menziesii* var. *glauca*), limber pine (*Pinus flexilis*), and ponderosa pine (*Pinus ponderosa*).

The sagebrush steppe in Bighorn Canyon is a mosaic of Wyoming big sagebrush (*Artemisia tridentata* var. *wyomingensis*), black sagebrush (*Artemisia nova*), bluebunch wheatgrass (*Pseudoroegneria spicata*), western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), threadleaf sedge (*Carex filifolia*), June grass (*Koeleria macrantha*), Sandberg bluegrass (*Poa secunda* var. *secunda*) and needle-and-thread grass (*Hesperostipa comata* var. *comata*).

Exposed sites subject to wind exposure are colonized by cushion plant communities. These communities are characterized by “low, woody, plant life form so densely branched that it forms a compact canopy that is pad- or bolster-like in appearance; usually with microphyllous foliage; characteristic of alpine and tundra plants” (FGDC 1997). The primary influencing environmental factor is wind; in most examples of this type, wind deflation has scoured a gravel-paved surface (NatureServe 2010) and the soils are shallow. Characteristic species include bluebunch wheatgrass, Fendler’s threeawn (*Aristida purpurea*), needle-and-thread, Hooker sandwort (*Arenaria hookeri)*, broom snakeweed (*Gutierrezia sarothrae*), fineleaf hymenopappus (*Hymenopappus filifolius*), squarestem phlox (*Phlox bryoides)* and Hood’s phlox (*Phlox hoodii*) (Knight et al. 1987). Despite the harshness of the setting and the ruggedness of the community, Heidel and Fertig (2000) found some of the most restricted flora in the park in these locations including the rare plants bighorn fleabane (*Erigeron allocates*), rabbit buckwheat (*Eriogonum brevicaule* var. *canum*), and Lesica’s bladderpod (*Lesquerella lesicii*).

2.4 Resource Stewardship

Management Directives and Planning Guidance

As a unit in the National Park System, Bighorn Canyon is responsible for the management and conservation of its natural resources. This primary mandate is supported by the National Park Service Organic Act of 1916, which directs the Park Service to:

> conserve the scenery and natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations.

The enabling legislation states the purpose of the national recreational area is to provide public recreational use and enjoyment (16 U.S.C. § 460t (a)) (NPS 2000), therefore management at the park is set within a recreational context. As a result of this and other laws and policies, management of this park is focused on visitor experience as well as the natural setting within which they occur while providing for human recreation and enjoyment.

Crow Tribal lands constitute nearly half of the 48,682 hectares (120,296 acres) within the legislated boundaries of the park. These lands are not owned by the federal government and are outside the jurisdiction of the NPS (Jacob et al. 1996). The NPS and the Crow agreed in a 1976 Memorandum of Agreement (MOA), to confine management planning and development within the boundaries of Bighorn Canyon National Recreation Area designated by Congress. Recognizing this MOA, resource management by the NPS is confined to the managed area boundary (Plate 4) and Crow Tribal lands are excluded from this assessment.

Three important NPS documents broadly guide the management of natural resources in the park; these are the General Management Plan (GMP) (NPS 1981), the Resource Management Plan (NPS 1995) and the National Park Service Management Policies (USDOI 2006). The GMP identifies specific management issues, sets forth management objectives and provides alternatives for addressing issues (NPS 1995). In all, these documents and the specific management directives below are used in this Natural Resource Condition Assessment as the fundamental source for setting natural resource reference conditions and defining specific areas of natural resource management interest.

The Pryor Mountain Wild Horse Range was created in 1968 by order of the Secretary, U.S. Department of the Interior, who directed that wild horses be managed in “a balanced program which considers all public values and without impairment of the productivity of the land” (Federal Register, Document 68-11056, 11 Sept. 1969; Bureau of Land Management, 2006, p. 5). The Bureau of Land Management (BLM) was designated as the lead agency for management of wild horses, though the range also contains lands administered by the U.S. Forest Service (USFS; Custer National Forest) and the National Park Service (NPS; Bighorn Canyon National Recreation Area). The Wild Free-Roaming Horses and Burros Act of 1971 (P.L. 92-195) further directed the USFS and BLM to manage wild horses at Pryor Mountain and wild horses and burros (*Equus asinus*) wherever they occur “in a manner that is designed to achieve a thriving natural ecological balance on the public lands ”(Roelle et al. 2010). A Herd Management Plan (BLM 1984) outlines management policies and guidelines that address natural resources.
The Yellowtail Wildlife Habitat Management Area (YWHMA) was established early in the 1960s to enhance waterfowl habitat at the confluence of the Shoshone and Bighorn Rivers. The YWHMA encompasses major portions of the southern end of the park and is managed as habitat for waterfowl and upland game birds, although a wide variety of plants and animals inhabit the area. The Wyoming Game and Fish Department manages the area under agreement with the NPS, the Bureau of Reclamation, and BLM. A number of important aquatic and wetland features exist on park lands in the Yellowtail Area. These include Railroad Pond, Kane Ponds, Cemetery Pond, and Ponds 612, 7, 9, and 10. In the case of Railroad Pond, the United States has received a

water right permit for maintaining a “fishing preserve”. The present boundaries of the YWHMA include 7,864 hectares (19,424 acres) of land and water, of which 60% are park lands (Jacobs et al. 1996).

The park’s Integrated Weed Management Program Environmental Assessment (NPS 2004) was completed in January 2004. The 2004 plan states:

> weed control is considered to be critical part of management of vegetative communities to enhance biodiversity and maintain the native species. The park has identified five different management zones based upon the types of weeds that are problematic, the amount and type of disturbance, management goals and the condition of the underlying vegetative communities. They are: 1) developed visitor/administrative facilities highly disturbed with desired maintenance of lawns, gravel surfaces, concrete etc. 2) historic ranches- previously heavily disturbed with some restoration activities, goal is maintenance and restoration of the cultural landscape 3) recreation facility areas- campgrounds and picnic areas, ongoing disturbance, goal is maintenance of an attractive environment utilizing native vegetation as much as possible 4) roadways/trailing routes- high disturbance and high rate of introduction of new alien plants, goal is safety, good esthetic appearance and prevention of dissemination of noxious weeds 5) natural areas excluding high waterline areas around the reservoir, goal is maintaining as healthy a native plant community as possible with no spread of alien plants from the reservoir area.

The park’s Fire Management Plan was completed in October 1999, approved in 2004 and amended in 2009 (NPS 2009a). Bighorn Canyon has an active prescribed fire program designed to reduce hazardous fuels and improve wildlife habitat throughout the southern end of the park. Heavy understory fuels in some of the woodlands and accumulated drift wood in the YWHMA adds to fire intensity and overall resistance to control (NPS 2009a). Prescribed fire in the YHHMA is used to reduce noxious weeds and exotic plants and reduce hazardous fuels for the benefit of game and non-game species. In addition to utilizing prescribed fire as a tool for fuels reduction, other biological, chemical, and mechanical means to treat fuels are used in areas around developments or historic sites, and to supplement prescribed fire in reducing noxious plants.

The Water Resources Management Plan (Jacobs et al. 1996) was designed to serve as a tool to guide the management of water resources by the park over a period of 10 to 15 years after publication. The plan begins with a thorough overview of the hydrologic environment and concludes with specific actions to address water resources issues. Management issues related to water resources were organized in two categories: 1) needs related to providing a safe and aesthetic recreational experience for park visitors, and 2) water-related management issues brought about by past and present land-use practices. Several project statements within the Water Resources Management Plan describe the problem statement and a description of the recommended project or activity.

Resource Issues Overview

Bighorn Canyon faces a number of resource management issues, many of which are related to management of the reservoir, wild horse management in the PMWHR and invasive plant management in YWHMA. A synthesis of geologic resources issues by the NPS Geologic Resource Division (KellerLynn 2011) found lake sedimentation and its impacts as a critical issue in Bighorn Canyon. They report that the most notable sedimentation is occurring in the upper reaches, where sediment accumulation is a particular problem at Horseshoe Bend, the major visitor-use facility for the south end of the lake (NPS 2005). Sedimentation buildup at the head of the reservoir has raised the amount of water needed to keep the Horseshoe Bend boat ramp usable. Originally, the ramp could be used down to a water elevation of 1,094 meters (3,590 feet). As a result of sedimentation, however, the ramp is no longer usable when the water drops below 1,102 meters (3,617 feet) (BOR 2010).

Other resource issues include disturbed and abandoned mineral lands. Abandoned access roads are associated with past land uses, such as mining and exploration, and ranching activities have significantly disturbed localized areas of the landscape. Disturbed habitats are susceptible to plant invasions and the impacts of past and continuing disturbances are noticeable throughout the park. Weed inventories show that weedy areas are primarily associated with historic ranches, old agricultural fields, irrigation ditches, reservoir flood pool during years of low water, cattle trailing routes, and the wild horse range, all related to cultural landscapes and traditions of arid land use (NPS 2004).

The most common "weeds" targeted for control include the state listed noxious weeds - spotted knapweed (*Centaurea stoebe*), diffuse knapweed (*Centaurea diffusa*), Russian knapweed (*Acroptilon repens*), tamarisk (*Tamarix chinensis*), whitetop (*Cardaria* sp.), leafy spurge (*Euphorbia esula*), field bindweed (*Convolvulus arvensis*), Canada thistle (*Cirsium canadensis*), bull thistle (*Cirsium vulgare*), houndstongue (*Cynoglossum officinale*), and other state listed species if found.

Fluctuating reservoir levels, hydrologic flows, and the formation of point bars and sediment flats encourage the invasion of nonnative species, such as tamarisk and Russian olive (*Elaeagnus angustifolia*), which rapidly spread into unvegetated or disturbed areas (NPS 2005).

Herding of cattle also occurs through designated portions of the park as herds pass between private lands or from private to public grazing lands outside the park. Present-day cattle trailing and wild horse grazing impact vegetation and fragile soil crusts, leaving bare areas susceptible to wind and sheetwash erosion (KellerLynn 2011). Precipitation in lower elevation areas often comes in the form of thunderstorms that cause severe erosion of sparsely-vegetated soils and increase sediment loads in the rivers (WY DEQ 2010, as cited in Sigler 2011). Wild horse population numbers and limited range capacity impact range condition in the PRWHR and areas inside Bighorn Canyon are in poor range condition (Ricketts 2004).

Montana and Wyoming have identified waters in BICA that do not meet state surface water standards and are listed as 303(d) impaired. Crooked Creek is listed by Montana DEQ because of physical substrate habitat alteration leading to partial impairment for aquatic life and coldwater fisheries (MT DEQ 2012). In Wyoming the DEQ listed Crooked Creek as impaired due to flow alterations (WY DEQ 2010, as cited in Sigler 2011). The Shoshone River near Lovell, WY is listed for fecal bacteria and the Big Horn River at St. Xavier in Montana is listed for nitrogen (WY DEQ 2010, as cited in Sigler 2011).

Woods and Corbin (2003) state an issue of concern for water quality in Bighorn Canyon is the bioaccumulation of pesticides, herbicides, polychlorinated biphenyl (PCB), and mercury in fish in Bighorn Lake, leading to potential toxicity in humans who eat contaminated fish and shellfish. The Water Resources Division (NPS 1998) identified rivers upstream of Bighorn Canyon that run through agricultural areas as having elevated nutrient loads, and there is concern that high nutrient concentration in Bighorn Lake contribute to the eutrophic nature of Bighorn Lake.

Resource extraction surrounding BICA is ongoing and an inventory of active mining claims in 2004 (Napoli et al. 2004) found over 3,600 active sites within 20 miles of the recreation area at that time. In addition, one active mine claim exists within the park boundary (C. Bromley, pers. comm., 2012) The majority of this activity is concentrated around the southern section of the recreation area and consists mainly of placer claims (over 1,500). The remainder of the active sites are lode claims (over 550), oil and gas leases (182), and a mix of fiber optics and gypsum claims.

2.5 Status of Supporting Science

In addition to NPS staff recommendations, the Greater Yellowstone Network Inventory and Monitoring (I&M) Program Vital Signs (Jean et al. 2005) guided the selection of key natural resources for this report (Table 1). The I&M Program was established to collect, organize, and provide natural resource data as well as information derived from data through analysis, synthesis, and modeling (NPS 2009) to improve park management through expanded use of scientific knowledge.

Table 1. Bighorn Canyon National Recreation Area Vital Signs.

Level I	Level II	Vital Sign
Air and Climate	Air Quality	Atmospheric deposition
	Weather	Climate
Geology and Soils	Geomorphology	Stream sediment transport
	Subsurface geologic processes	Seismic activity
	Soil Quality	Soil biota
		Soil structure and stability
Water	Hydrology	Ground water quantity
		Arid seep and spring
		Reservoir and lake elevation
		Streamflow
	Water quality	Biogeochemical flux
		Water chemistry
		Ground water quality
		E-coli
		Water temperature
		Algae
		Aquatic invertebrate assemblages
Biological integrity	Invasive species	Invasive plants
		Exotic aquatic assemblages
	Infestations and disease	Forest insects and disease
		Vertebrate disease
	Focal species or communities	Riparian/riverine
		Native aquatic assemblages
		Shrub-steppe
		Insects
		Amphibians
		Landbirds
		Beaver
		Meso-carnivores
		Ungulates
		Cushion Plants
	At-risk biota	Large carnivores
		Birds of concern
Human use	Visitor and Recreation Use	Visitor use
Ecosystem pattern and processes	Fire	Fire
	Land cover and use	Land cover
		Land use
	Soundscape	Soundscapes

Available data and reports vary significantly depending on the resource; however, the presence of data was not a criterion for the selection of resources used in this assessment. In addition to data from the I&M Program and reports and data supplied by park staff and/or obtained from the

NPS IRMA database, the Bureau of Reclamation, Natural Resource Conservation Service (NRCS), and U.S. Geological Survey (USGS) provided significant data.

In addition, GRYN and BICA work through Cooperative Ecosystems Studies Units (CESU) to accomplish a number of science-related goals:

- provide usable knowledge to support informed decision making;
- ensure the independence and objectivity of research;
- create and maintain eff ective partnerships among the federal agencies and universities to share resources and expertise;
- take full advantage of university resources while benefi ting faculty and students;
- encourage professional development of current and future federal scientists, resource managers, and environmental leaders; and
- manage federal resources effectively (CESU 2012).

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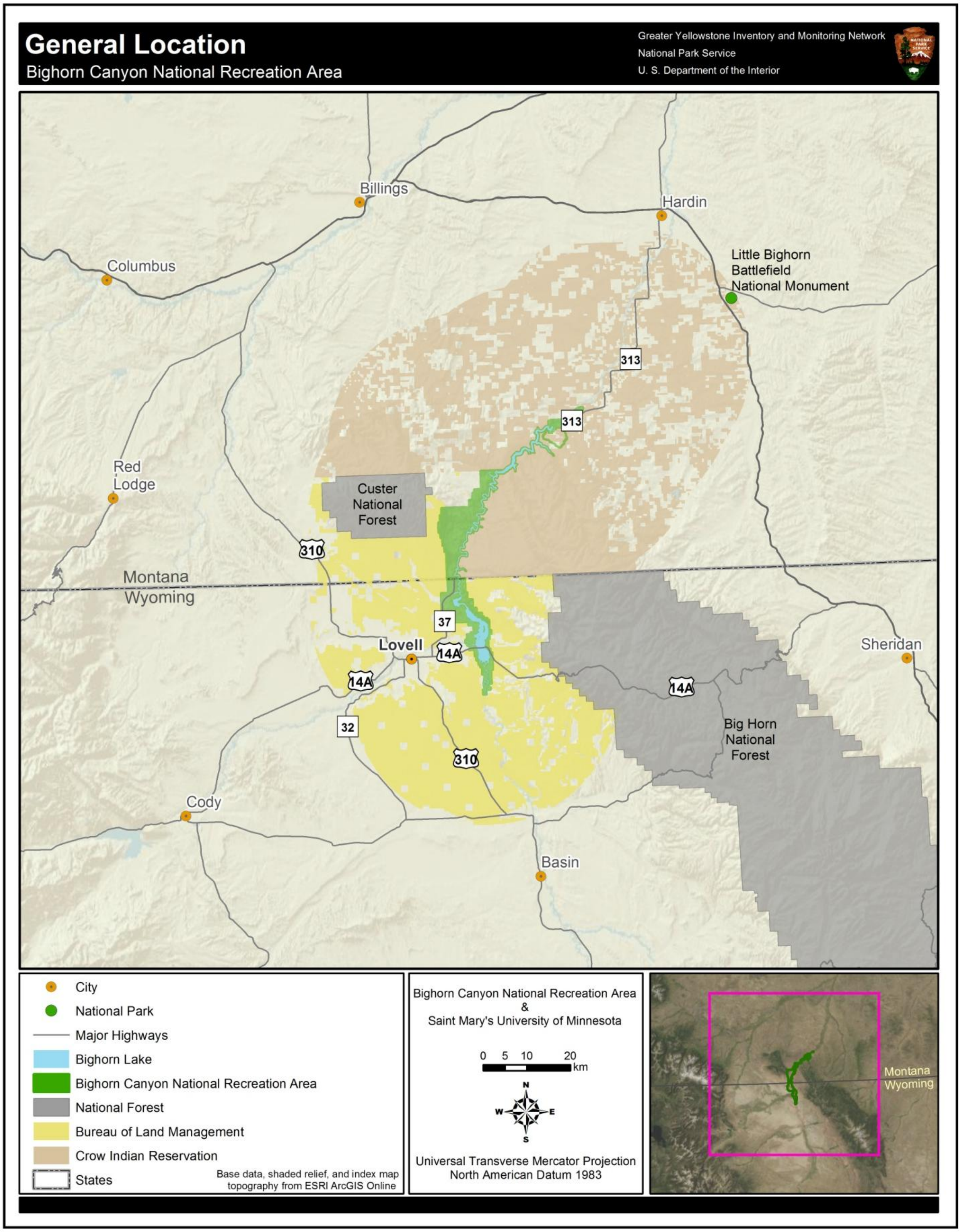

Plate 1. Map showing the location of Bighorn Canyon National Recreation Area in Montana and Wyoming, USA.

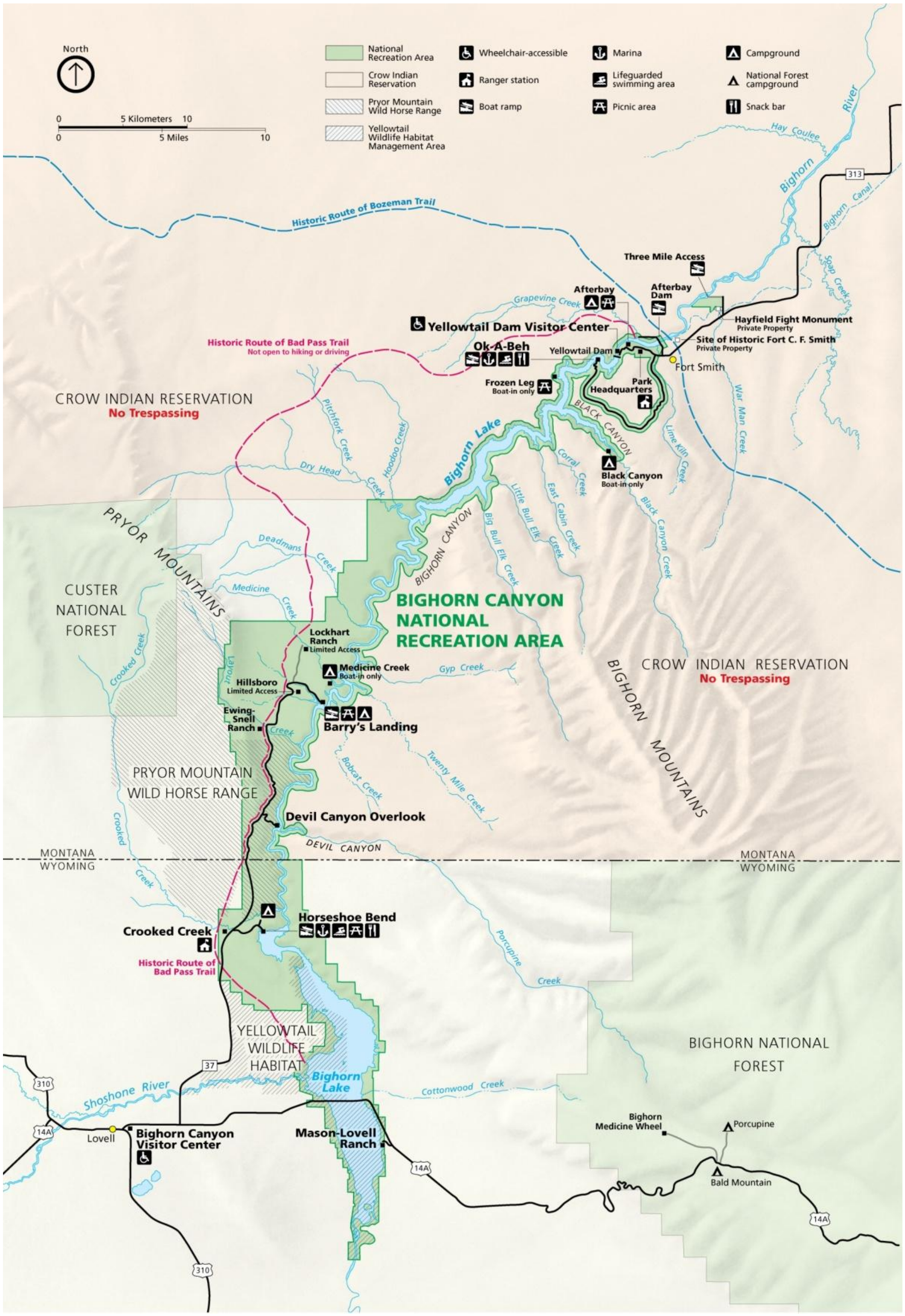

Plate 2. Park map for Bighorn Canyon National Recreation Area.

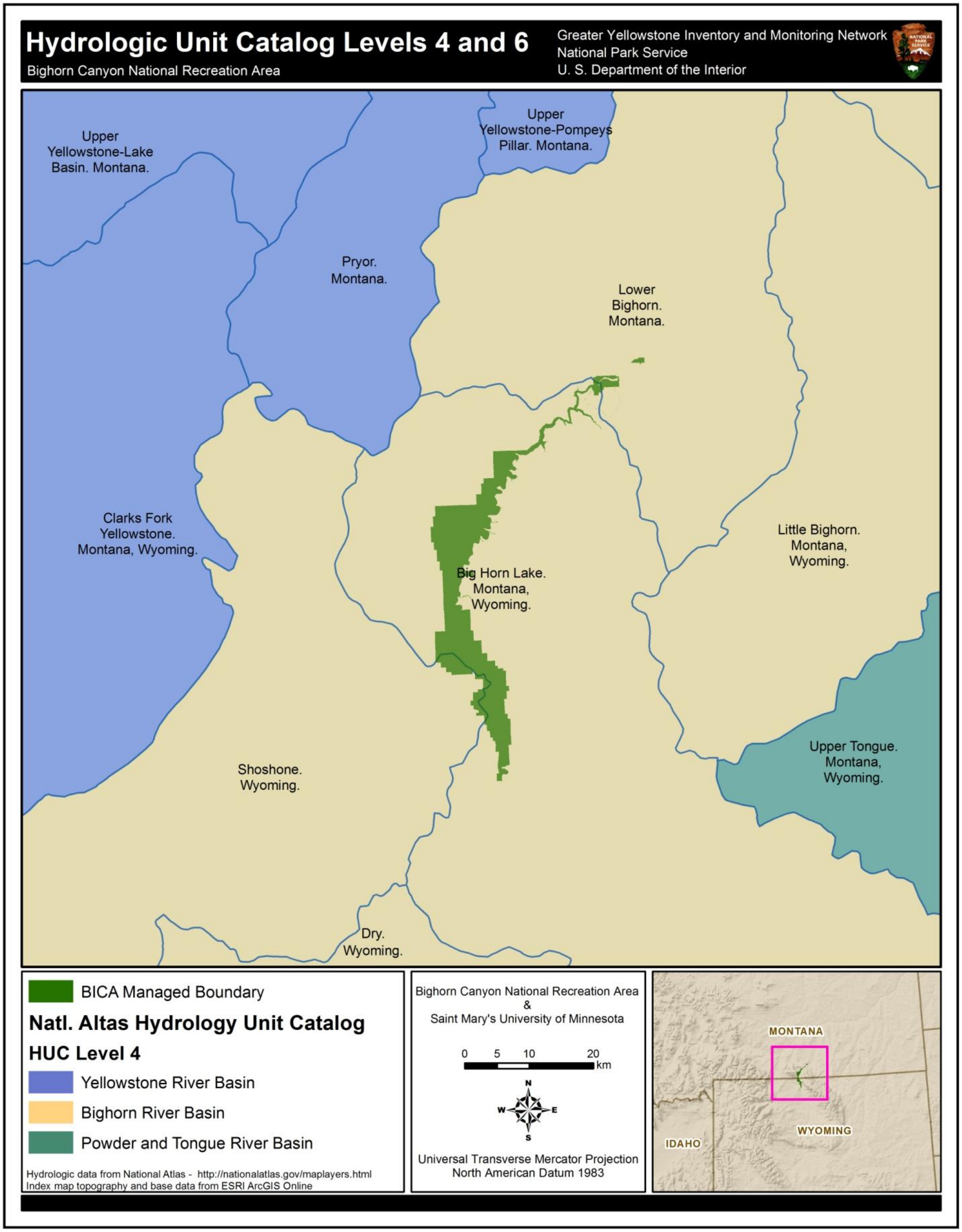

Plate 3. Hydrololgic Units of Bighorn Canyon National Recreation Area. Data source: USGS National Atlas Hydrologic Unit Catalog.

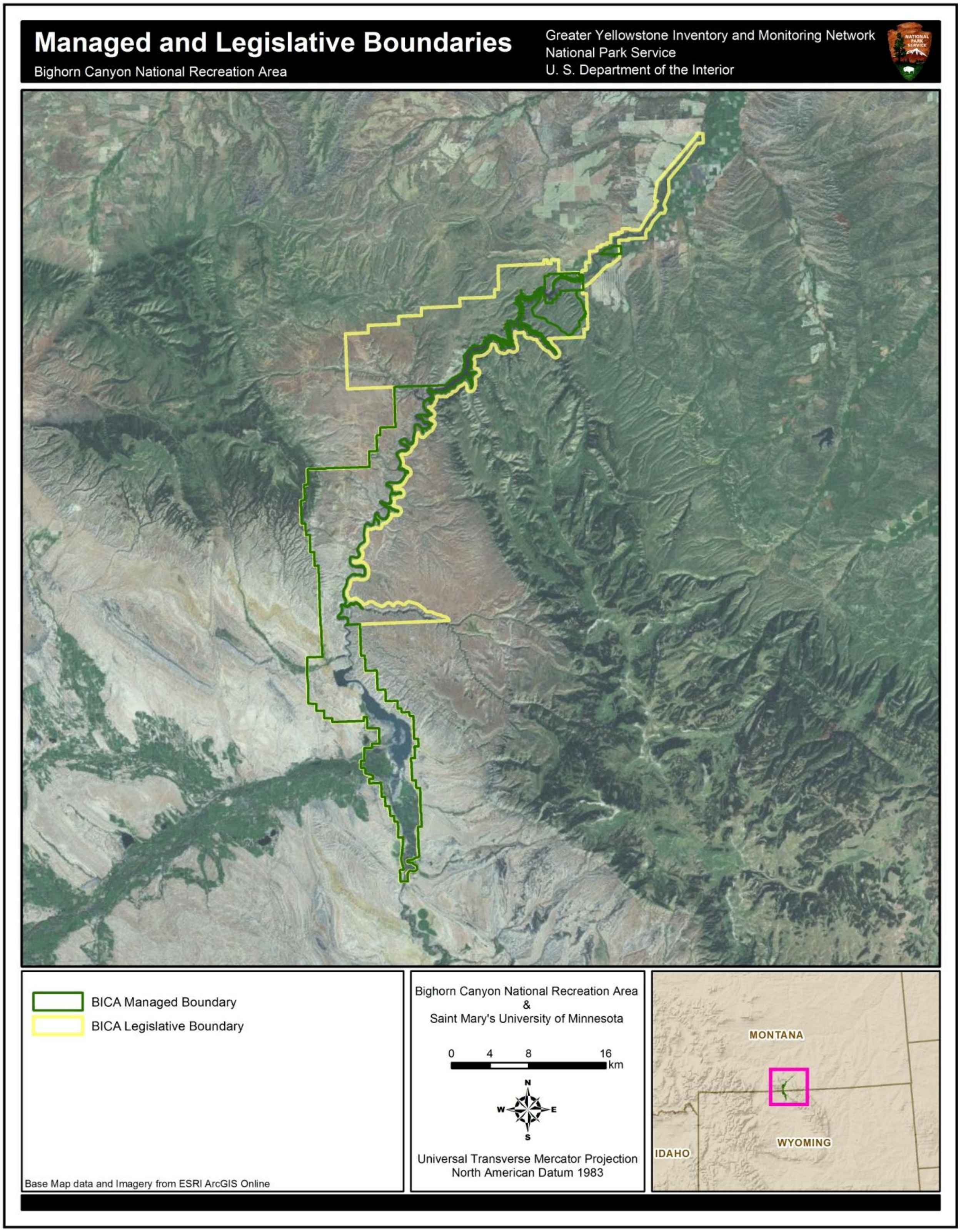

Plate 4. Legislative and managed area park boundaries for Bighorn Canyon National Recrreation Area.

Chapter 3 Study Scoping and Design

This NRCA is a collaborative project between the National Park Service (NPS) and Saint Mary's University of Minnesota Geospatial Services (SMUMN GSS). Project stakeholders include the BICA resource management team, and GRYN Inventory and Monitoring Program staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMUMN GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created cooperatively between the NPS and SMUMN GSS.

3.1 Preliminary scoping

A preliminary scoping meeting was held on 31 August-1 September 2010. At this meeting, SMUMN GSS and NPS staff confirmed that the purpose of the BICA NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition influences of concern to BICA managers. Certain constraints were placed on this NRCA, including the following:

- Condition assessments are conducted using existing data and information.
- Identification of data needs and gaps is driven by the project framework categories.
- The analysis of natural resource conditions includes a strong geospatial component.
- Resource focus and priorities are primarily driven by BICA resource management.

This condition assessment provides a "snapshot-in-time" evaluation of the condition of a select set of park natural resources that were identified and agreed upon by the project team. Project findings will aid BICA resource managers in the following objectives:

- Develop near-term management priorities (how to allocate limited staff and funding resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Consider new park planning goals and take steps to further these;
- Report program performance (e.g., Department of Interior Strategic Plan "land health" goals, Government Performance and Results Act [GPRA]).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available data, reports, and spatial information from appropriate sources including: BICA resource staff, the NPS Integrated Resource Management Application (IRMA) website, Inventory and Monitoring Vital Signs, and available third-party sources. The NRCA report will provide a resource assessment and summary of pertinent data evaluated through this project.

- When appropriate, define a reference condition so that statements of current condition may be developed. The statements will describe the current state of a particular resource with respect to an agreed upon reference point.

- Clearly identify "management critical" data (i.e., those data relevant to the key resources). This will drive the data mining and gap definition process.

- Where applicable, develop GIS products that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.

- Utilize "gray literature" and reports from third party research to the extent practicable.

3.2 Study Design

Indicator Framework, Focal Study Resources and Indicators

Selection of Resources and Measures

As defined by SMUMN GSS in the NRCA process, a "framework" is developed for a park or preserve. This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. The primary features in the framework are key resource components, measures, stressors, and reference conditions.

"Components" in this process are defined as natural resources (e.g., birds), ecological processes or patterns (e.g., natural fire regime), or specific natural features or values (e.g., geological formations) that are considered important to current park management. Each key resource component has one or more "measures" that best define the current condition of a component being assessed in the NRCA. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a component. In addition to measures, current condition of components may be influenced by certain "stressors," which are also considered during assessment. A "stressor" is defined as any agent that imposes adverse changes upon a component. These typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation (adapted from GLEI 2010).

During the BICA NRCA scoping process, key resource components were identified by NPS staff and are represented as "components" in the NRCA framework. While this list of components is not a comprehensive list of all the resources in the park, it includes resources and processes that are unique to the park in some way, or are of greatest concern or highest management priority in BICA. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

Selection of Reference Conditions

A "reference condition" is a benchmark which current values of a given component's measures can be compared to determine the condition of that component. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal/objective (e.g., a bison herd of at least 200 individuals) (adapted from Stoddard et al. 2006).

Reference conditions in this project were identified during the scoping process using input from NPS resource staff. In some cases, reference conditions represent a historical reference before human activity and disturbance was a major driver of ecological populations and processes, such as “pre-fire suppression.” In other cases, peer-reviewed literature and ecological thresholds helped to define appropriate reference conditions.

Finalizing the Framework

An initial framework was adapted from the organizational framework outlined by the H. John Heinz III Center for Science’s “State of Our Nation’s Ecosystems 2008” (Heinz Center 2008). Key resources for the park were adapted from the GRYN Vital Signs monitoring plan (Jean et al. 2005). This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMUMN GSS analysts and NPS staff was needed to focus the scope of the NRCA project and finalize the framework of key resources to be assessed.

The NRCA framework was finalized in April 2011 following acceptance from NPS resource staff. It contains a total of 17 components (Table 2) and was used to drive analysis in this NRCA. This framework outlines the components (resources), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each component for comparison to current conditions.

Table 2. Bighorn Canyon National Recreation Area natural resource condition assessment framework.

Component	Experts	Data Sources	Measures	Stressors	Reference Condition
Biotic Composition					
Ecological Communities					
Cottonwood-dominated Woodlands	Suzanne Morstad	Vegetation Map, Aerial photography, Bighorn Cottonwood Thesis (Akashi 1988);	Extent of Woodland Area (2), Age Class Diversity (3), Exotic Species Distribution and Abundance (3)	Fewer flood events due to hydrologic modification, Disease (oystershell scale),	Not defined
Cushion Plant Community	Suzanne Morstad	USGS Range Exclosure Study, Vegetation Map, Wild Horse Range Condition Assessment	Species Richness/Diversity (3), Total Area (2), Percent Coverage of Cryptogametic Soil (3)	Grazing and trampling; exotic plant invasion; succession	Not defined
Sagebrush Steppe Community	Cathie Jean, Matt Rickets	Teton Fire Effects Group, USGS Range Exclosure Study, Vegetation Map, Horse Range Condition Assessment, I&M Data	Species Richness/Diversity (3), Encroachment of Juniper into Sagebrush Steppe (2), Proportion of Native to Non-Native Species (3), Relative abundance of protected vs. bare ground (3)	Grazing and trampling; exotic plant invasion	Not defined
Juniper/Pine/ Mountain Mahogany Community	Cathie Jean, Matt Ricketts	Teton Fire Effects Group, USGS Range Exclosure Study, Vegetation Map, Horse Range Condition Assessment	Total Area (2), Recruitment of Mountain Mahogany (3), Percent Native to Non-Native Species (2), Species Diversity, Presence/Absence of Pine (2), Juniper Density (3)	Grazing pressure on mountain mahogany; fire suppression (or lack of fire) on juniper communites; exotic plant invasion, exotic plant invasion	Knight et al. (1987) when appropriate depending on measure.
Mammals					
Bighorn Sheep	Rob Kissell, Shawn Stewart	USGS and Kissell Studies	Population Size (3), Lamb Recruitment (3), Mortality (3), Rainfall (2), Forage (2), Disease (1)	Loss of secure habitat; mountain lions (?); forage and water availability	Measure dependent, R. Kissell provided input.
Wild Horses	Jared Bybee, Matt Dillon	USGS Range Exclosure Study	Forage (3), Water (3), Cover and Space (2), Population Size [Appropriate Management Level] (3), Herd Health [Genetic Diversity, Reproductive Success] (2)	Range condition (e.g. forage availability)	Appropriate Management Levels (BLM), Ricketts et al. 2004
Bats	Doug Keinath	Keinath Bat Inventory (2005)	Presence/Absence of WNS (2), Change in site occupation in Park (2), Relative Abundance (3), Colonial Roost Abundance (3), Environmental Conditions of Colonial Roosts (1).	White nose syndrome	Keinath DA. 2005. Bat Inventory of the Greater Yellowstone Network: Final Report.
Birds					
Game Birds	Tom Easterly	WYG&F is willing to provide data upon request.	Turkey Abundance (3), Take per Unit Effort (3), Pheasant Abundance (3), Waterfowl Abundance (2) Sandhill Crane Abundance (1), Mourning Dove Abundance (1), Habitat Suitability (3), Number of Ponds with Water per Year (2)	Land cover change, West Nile Virus, harvest	Not defined
Land birds	Chris White, Nick Van Lanen	Birds thesis (Cottonwood Riparian), RMBO information and data, CBC data, NABBS data	Population Estimates for Common Breeding Bird Species (3), Presence/Absence of Priority Species (2), Species Richness (2)	Loss of nesting habitats due to changes in vegetation structure; phenology of nesting habitats	White et al. 2011 transect data
Peregrine Falcons	Jay Sumner	MT Peregrine Institute Research,	Nesting Population Size (3), Productivity - average young/nesting pair (3), Annual Percent Occupancy (3)	No specific threats to birds in BICA, potentially west nile virus, but this is an isolated threat.	Nesting population of 3-4 pairs (Jay Sumner)
Fish					
Bighorn Lake species	Mike Ruggles, Mark Smith	State Yearly Reports, Gill net survey data	Angling Pressure/Harvest (1), AIS Prevention and Monitoring (2), Species Composition and Abundance (3), Mercury (1), Sedimentation (2), Turbidity (2)	Mercury accumulation in fish; reduced area for rearing young fish; (potential for Aquatic Invasive Species in the reservoir)	Measure dependent, M. Ruggles and M. Smith provided input.
Tailwater Trout Fishery	Mike Ruggles, Ken Frazer	State Yearly Reports,	Angler Days (2), Mercury (1), Flow (3), Trout/River Mile (3), Reproduction (2)	Regulated river flow; (recreation and the potential of accidental introduction of Aquatic Invasive Species)	Measure dependent, M. Ruggles provided input.
Environmental Quality					
Water Quality	Jeff Arnold, Cathie Jean	NPStoret, EPA Storet, WRD Horizon Data, WY and MT state data	pH (3), DO (3), Water Temperature (3), Macroivertebrates (3), E. Coli (2), Presence of Pesticides (1)	Increased water temperature, E-coli concentrations on the Shoshone River; reduced flow on Crooked Creek;	EPA Standards
Viewscape	Melanie Myers	NPScape, Network Data, Park GIS Data	Measures identified subsequent to framework development by Melanie Myers and park staff.	Non-natural features (potential for development, especially on crow tribe lands visible from Devil's Canyon overlook)	Not defined
Physical Characteristics					
Seeps and Springs	Cathie Jean, Denine Schmitz, Dave Stagliano	Data from D. Scmidt and D. Stagaliano	Discharge (CFS or GPM) (3), Change in pH, DO, Water Temp (2), Macroinvertebrates (2), Extent of Area Influenced by Spring (3)	Water diversions, damming and groundwater pumping	Pristine springs - EPA, Montana, and Wyoming water quality standards.
Erosion	Judson Finley, Cathie Jean	I&M Soil Aggregrate Stability data (2007 & 2008)	Sediment Deposition (3), Soils (type and stability) (3), Vegetation (3), Climate Variability (3)	Loss of protective soil cover	Not defined
Visitor Experience as Affected by Surface Water Hydrology	Stephanie Micek, Lenny Duberstein, Dan Jewell, Tom Sawatzke	Data provided or identified by BOR	Lake Levels (BOR) (3), Sedimentation (2)	Sediment accumulation at Horseshoe Bend Marina; low resevoir levels; invasive species colonizing floodplain when resevoir is low	Minimum elevation levels identified by BOR

General Approach and Methods

This study involved gathering and reviewing existing literature and data relevant to each of the key resource components included in the framework. No new data were collected for this study; however, where appropriate, existing data were further analyzed to provide summaries of resource condition or to create new spatial representations. After all data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and compared to the reference condition when possible.

Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the initial scoping meeting, at which time BICA staff provided data and literature in multiple forms, including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data, and charts. GIS data were provided by NPS staff. Additional data and literature were also acquired through online bibliographic literature searches and inquiries on various state and federal government websites. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality regarding the resource components identified at the scoping meeting.

Data Development and Analysis

Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available for the component and recommendations from NPS reviewers and sources of expertise including NPS staff from BICA and the GRYN. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Scoring Methods and Assigning Condition

A set of measures are useful in describing the condition of a particular component, but all measures may not be equally important. A "significance level" represents a numeric categorization (integer of 1-3) of the importance of each measure in explaining the condition of the component; each significance level is defined in Table 3. This categorization allows measures that are more important for determining condition (higher significance level) of a component to be more heavily weighted in calculating an overall condition.

Table 3. Scale for a measure's significance level in determining a components overall condition.

Significance Level (SL)	Description
1	Measure is of low importance in defining the condition of this component.
2	Measure is of moderate importance in defining the condition of this component.
3	Measure is of high importance in defining the condition of this component.

After each component assessment is completed (including any possible data analysis), a condition level is assigned for each measure. This is based on a 0-3 integer scale and reflects the data mining efforts and communications with park experts (Table 4).

Table 4. Scale for condition level of individual measures.

Condition Level (CL)	Description
0	Of **NO** concern. No net loss, degradation, negative change, or alteration.
1	Of **LOW** concern. Signs of limited and isolated degradation of the component.
2	Of **MODERATE** concern. Pronounced signs of widespread and uncontrolled degradation.
3	Of **HIGH** concern. Nearing catastrophic, complete, and irreparable degradation of the component.

After the significance levels (SL) and condition levels (CL) are assigned, a weighted condition score (WCS) is calculated via the following equation:

$$WCS = \frac{\sum_{i=1}^{\#\ of\ measures} SL_i * CL_i}{3 * \sum_{i=1}^{\#\ of\ measures} SL_i}$$

The resulting WCS value is placed into one of three possible categories: condition of low concern (WCS = 0.0 – 0.33); condition of moderate concern (WCS = 0.34 - 0.66); and condition of significant concern (WCS = 0.67 to 1.00). Figure 1 displays all of the potential graphics used to represent a component's condition in this assessment. The colored circles represent the categorized WCS; red circles signify a significant concern, yellow circles a moderate concern and green circles a condition of low concern. Gray circles are used to represent situations in which there is currently insufficient data to make a statement about the condition of a component. The arrows inside the circles indicate the trend of the condition of a resource component. An upward pointing arrow indicates the condition of the component has been improving in recent times. A right-pointing arrow indicates a stable condition or trend and an arrow pointing down indicates a decline in the condition of a component in recent times. These are only used when it is appropriate to comment on the trend of condition of a component. A gray, triple-pointed arrow is reserved for situations in which the trend of the component's condition is currently unknown.

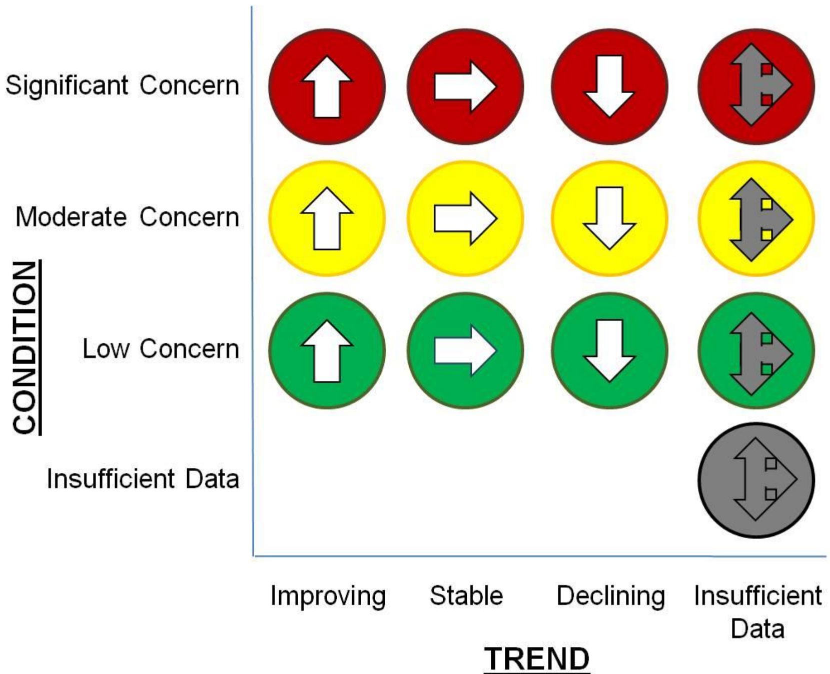

Figure 1. Symbols used for individual component assessments with condition or concern designations along the vertical axis and trend designations along the horizontal.

Preparation and Review of Component Draft Assessments
The preparation of draft assessments for each component was a highly cooperative process among SMUMN GSS analysts and BICA and GRYN staff. Though SMUMN GSS analysts rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also plays a significant and invaluable role in providing insights into the appropriate direction for analysis and assessment of each component. This step is especially important when data or literature are limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or conference call with an individual or multiple individuals considered local experts on the resource components under examination. These conversations were a way for analysts to verify the most relevant data and literature sources that should be used and also to formulate ideas about current condition with respect to the NPS staff opinions. Upon completion, draft assessments were forwarded to component experts for initial review and comments.

Development and Review of Final Component Assessments
Following review of the component draft assessments, analysts used the review feedback from resource experts to compile the final component assessments. As a result of this process, and based on the recommendations and insights provided by BICA resource staff and other experts, the final component assessments represent, the most relevant and current data available for each component and the sentiments of park resource staff and resource experts.

Format of Component Assessment Documents
All resource component assessments are presented in a standard format. The format and structure of these assessments is described below.

Description
This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. For example, a component may represent a unique feature of the park, it may be a key process or resource in park ecology, or it may be a resource that is of high management priority in the park. Also emphasized are interrelationships that occur among a given component and other resource components included in the broader assessment.

Measures
Resource component measures were defined in the scoping process and refined through dialogue with resource experts. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items.

Reference Conditions/Values
This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions. If these conditions or values originated with the NPS experts or SMUMN GSS analysts, an explanation of how they were developed is provided.

Data and Methods
This section includes a discussion of the data sets used to evaluate the component and if or how these data sets were adjusted or processed as a lead-up to analysis. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for the reader or a GIS metadata file. Also discussed is how the data were evaluated and analyzed to determine current condition (and trend when appropriate).

Current Condition and Trend
This section presents and discusses in-depth key findings regarding the current condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. Due to their low importance, measures that are assigned a significance level of 1 do not receive an in-depth analysis and are not addressed in the current condition section. These measures are briefly discussed in the overall condition section of the document (see below).

Threats and Stressor Factors
This section provides a summary of the threats and stressors that may impact the resource and influence to varying degrees the current condition of a resource component. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. However, these are elaborated on in this section to create a summary of threats and stressor based on a combination of available data and literature, and discussions with resource experts and NPS natural resources staff.

Data Needs/Gaps
This section outlines critical data needs or gaps for the resource component. Specifically, what is discussed is how these data needs/gaps, if addressed, would provide further insight in

determining the current condition or trend of a given component in future assessments. In some cases, the data needs/gaps are significant enough to make it inappropriate or impossible to determine condition of the resource component. In these cases, stating the data needs/gaps is useful to natural resources staff who wish to prioritize monitoring or data gathering efforts.

Overall Condition
This section provides a qualitative summary statement of the current condition that was determined for the resource component using the WCS method. Condition is determined after thoughtful review of available literature, data, and any insights from NPS staff and experts, which are presented in the Current Condition and Trend section. The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that analysts attribute to the condition of the resource component. Also included in this section are the graphics used to represent the component condition.

Sources of Expertise
This is a listing of the individuals (including their title and affiliation with offices or programs) who had a primary role in providing expertise, insight, and interpretation to determine current condition (and trend when appropriate) for each resource component.

Literature Cited
This is a list of formal citations for literature or datasets used in the analysis and assessment of condition for the resource component. Note, citations used in appendices and plates referenced in each section (component) of Chapter 4 are listed in that section's "Literature Cited" section.

3.3 Literature Cited

Great Lakes Environmental Indicators Project (GLEI). 2010. Glossary, Stressor. http://glei.nrri.umn.edu/default/glossary.htm. (accessed 9 December 2010).

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The H. John Heinz III Center for Science, Economics, and the Environment. 2008. The state of the nation's ecosystems 2008: Measuring the land, waters, and living resources of the United States. Island Press, Washington, D.C.

Stoddard. J. L., D. P. Larsen, C. P. Hawkins, R. K. Johnson, and R. J. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications. 16(4):1267-1276.

Chapter 4 Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 17 key resource components in the project framework. The following sections discuss the key resources and their measures, stressors, and reference conditions. The summary for each component is arranged around the following sections:

1. Description
2. Measures
3. Reference Condition
4. Data and Methods
5. Current Condition and Trend (including threats and stressor factors, data needs/gaps, and overall condition)
6. Sources of Expertise
7. Literature Cited

The order of components follows the project framework (Table 2):

4.1 Cottonwood-dominated Woodlands
4.2 Cushion Plant Community
4.3 Sagebrush Steppe Community
4.4 Juniper/Pine/Mountain Mahogany Community
4.5 Bighorn Sheep
4.6 Wild Horses
4.7 Bats
4.8 Game Birds
4.9 Land Birds
4.10 Peregrine Falcons
4.11 Bighorn Lake Species
4.12 Tailwater Trout Fishery
4.13 Water Quality
4.14 Viewscape
4.15 Seeps and Springs
4.16 Erosion
4.17 Visitor Experience as Affected by Surface Water Hydrology

4.1 Cottonwood-dominated Woodlands

Description

The construction of several dams on the Bighorn and Shoshone Rivers altered the cottonwood forest composition within BICA. Cottonwood regeneration is rare along the Bighorn River, likely due to the suppression of spring floods associated with flow regulation by the dams (Knight et al. 1987). Today, riparian woodlands occurring along the Bighorn and Shoshone Rivers are dominated by the plains cottonwood (*Populus deltoides*) (Knight et al. 1987). Associated tree species include the peach-leaf willow (*Salix amygdaloides*), silver buffaloberry (*Shepherdia argentea*), and the non-native species, Russian olive (*Elaeagnus angustifolia*), tamarisk (*Tamarix* sp.), and whitetop (*Cardaria draba*), among others (Knight et al. 1987). Currently, high concentrations of non-native species within the park's cottonwood stands increase the catastrophic fire risk (C. Bromley, pers. comm., 2012).

Measures

- Extent of woodland area
- Age class area
- Non-native species distribution and abundance

Reference Conditions/Values

The reference condition for cottonwood-dominated woodland communities in BICA is undefined. Akashi et al. (1988) sampled the riparian forest community at BICA, which provided data relevant to the measures used in this assessment; these data provide a benchmark for future comparison. However, Akashi et al. (1988) do not describe the forest community present when the river was unrestricted. The sustainability of cottonwood is dependent on a functional ecosystem that includes periodic flooding and recruitment.

In unrestricted river systems, meandering pattern helps control the vertical and horizontal distribution of vegetation communities on a river's floodplain and the rate of such meandering "is a major factor determining the proportion of the floodplain area in pioneer, transitional, and terminal forest types" (Johnson et al. 1976, p. 81). In addition, fluvial geomorphic processes such as channel narrowing and flood deposition create suitable sites for cottonwood establishment (Scott et al. 1996). However, the channel narrowing that often occurs after dam closure eventually restricts subsequent recruitment of riparian forests to areas along the channel margins (Johnson 1998). Multiple models (e.g., Mahoney and Rood 1998, Dixon and Turner 2006) describe the relationship between river stage patterns and cottonwood seedling establishment; such models could be used in the future to develop reference condition and management goals for the riparian forest community in BICA.

Data and Methods

Knight et al. (1987) describes the vegetation ecology at BICA, including the floodplain woodlands.

Akashi (1988) studied the dynamics of riparian vegetation along the Bighorn River in Wyoming, including the southern portion of BICA.

Current Condition and Trend

Extent of Woodland Area

Knight et al. (1987) characterized four riparian vegetation classifications in BICA: floodplain meadow, floodplain shrub-land, floodplain woodland, and creek woodland. The floodplain woodland classification is the most accurate depiction of the cottonwood-dominated woodlands. In 1987, Knight et al. (1987) found that floodplain woodland accounted for 607 hectares (1,500 acres) of the park, or 2.7% of the park's size (Plate 5). The 1987 estimate is the only available total-park acreage estimate available at this time.

Knight et al. (1987) also examined aerial photographs from a number of years prior to 1987: 1938, 1944, 1954, 1961, 1967, 1979, and 1981. The authors noted that rapid change was evident from the available photos, especially along the Bighorn River, and that the effects of flow regulation are apparent. The Shoshone River, which meets the Bighorn River in BICA, did not exhibit the same observable trends in cottonwood prevalence in the late 1980s that occurred along the Bighorn River. Some observers believe that the less-regulated and braided nature of the Shoshone allowed for continued cottonwood regeneration during the duration of available aerial photos (Knight et al. 1987).

Age Class Area

Akashi (1988) surveyed the riparian forest community within BICA, near the southernmost boundary of the park. Akashi grouped cottonwood woodlands into five age classes: very young (one to four years), young (5-29 years), middle-aged (30-54 years), old (55-79 years), and very old (≥80 years) (Akashi 1988).

In pre-dam river systems, sandbars tend to be both high enough and large enough to provide adequate bare seedbeds at the places seeds tend to be deposited. In unrestricted conditions, seed dispersal timing and annual peak flow coincide, resulting in seedlings appearing on the sandbars in a "banded" pattern running parallel to the river's channel. The mature cottonwood stands in BICA exhibited this appearance, suggesting that the mature cottonwoods had germinated and developed under unrestricted conditions.

In post-dam conditions, Akashi (1988) noted that cottonwood seed germination, when it occurred, tended to occur on point and lateral bars along islands. During the summer of 1985, Akashi observed that these were, in fact, the only sites with cottonwood seedlings. The altered regime of stream flow and reduced sandbar sizes appear to have been largely responsible for the failure in *Populus* reproduction since 1960s.

Akashi's study also indicates a correlation between vegetative reproduction and quality, on the one hand, and the age of the stand, on the other: older stands exhibit both lower quality vegetation and lower reproduction rates.

Non-native Species Distribution and Abundance

Knight et al. (1987) noted that weeds are typically restricted to small areas in BICA, with the exception of riparian areas where fire and flood suppression created ideal habitat for non-native species invasions, especially for saltcedar (*Tamarix chinensis*). Wood and Rew (2005) confirmed these findings and noted that Russian olive existed in much of the riparian area in YWHMA.

Within YWHMA, the understory is composed of a large percentage of non-native species (Figure 2).

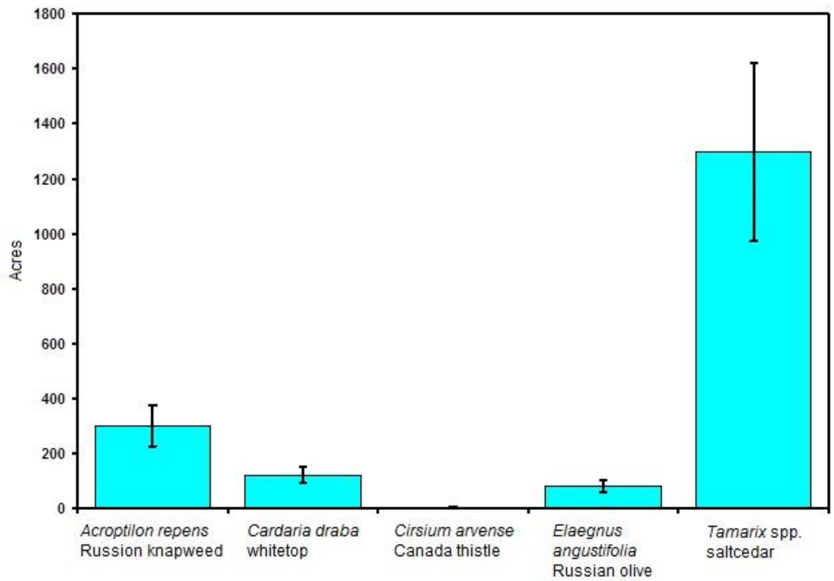


Figure 2. Non-native plant composition of areas mapped as gross areas; occurrence of gross areas was both inside and outside the survey area (Wood and Rew 2005).

Threats and Stressor Factors

The hydrology of the Bighorn River has been modified by dam construction, which has resulted in fewer and less dynamic flooding events. Annual peak streamflow averaged 16,500 cubic feet per second (cfs) between 1930 and 1951 and exhibited dynamic features with big peak flows and significant difference between the maximum and the minimum flows. After the construction of the Boysen Dam in 1952, annual peak streamflow fell to 10,300 cfs between 1952 and 1985; the big peaks were removed and the difference between maximum and minimum flow decreased (Akashi 1988). The dam has also greatly reduced the flood frequency on the river. Peak flow exceeded bankfull discharge 12 times in the 22 years prior to dam construction and only 4 years in the 34 years after construction (Akashi 1988).

Non-natives outcompete even cottonwood. Russian olive and tamarisk increase ladder fuels and fuel density, thus increasing the risk of catastrophic fire. Following a fire, regeneration can result in dominance of non-native over native plant species (C. Bromley, pers. comm., 2012).

Oystershell scale (*Lepidosaphes ulmi*) is an insect, which affects cottonwoods in BICA. There is no information available on the extent of the disease in the park.

Data Needs/Gaps

There has been little research on the cottonwood-dominated woodlands in BICA since the late 1980s. An updated vegetation inventory in the riparian area would provide more quantitative information to expand our knowledge regarding this component. The NPS Vegetation Inventory Program began a project in 2011 that includes a floristic inventory, plant community classification, and an updated map of current vegetation. The project acquired new high-resolution satellite imagery (0.5- m^2 resolution) and interpretation or remote-sensing techniques could provide the park with updated extent data for future assessments and management decisions.

<u>Overall Condition</u>

Extent of Woodland Area

Even though recent estimates of woodland area (*Significance Level*=2) do not exist for the park, the effects of flow regulation on cottonwood regeneration in the park are apparent. Knight et al. (1987) and Akashi (1988) both found that cottonwood regeneration along the Bighorn River declined following upriver flow regulation at Boysen Dam. Until natural spring flood pulses occur, it is reasonable to believe that cottonwood regeneration will be minimal and the area occupied by the associated woodlands along the Bighorn River will decline. Therefore, a *Condition Level* of 3 is appropriate for this measure.

Age Class Area

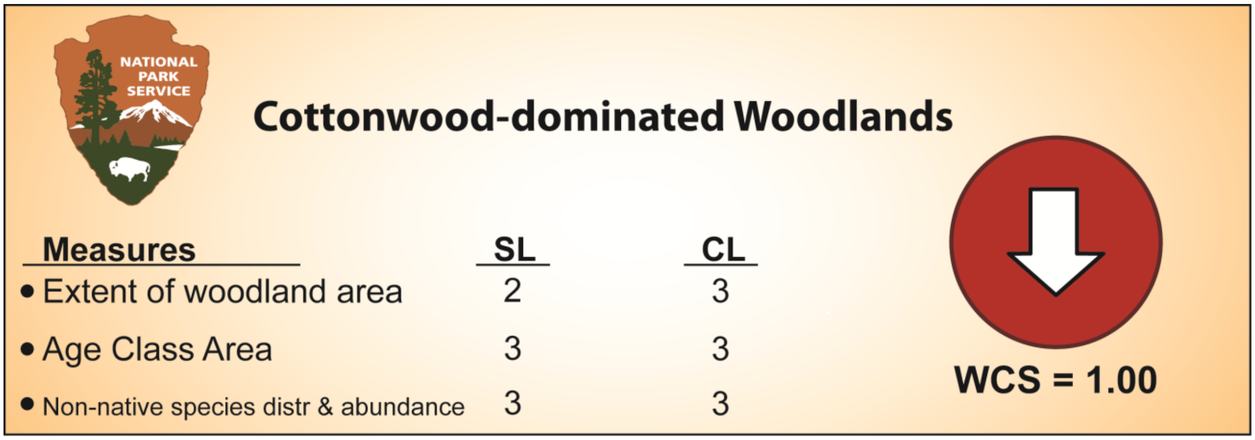
Age class area (*Significance Level*=3) was also altered by flow regulation on the Bighorn River. Due to the decline in regeneration, many of the park's cottonwood forests are aging without replacement. As this process continues, the age structure of cottonwood-dominated woodlands will shift towards an old age-dominant structure, rather than the diverse structure that was present prior to flow regulation. Given the changes of age structure since Boysen Dam closed in 1952, the *Condition Level* of this measure is a 3.

Non-native Species Distribution and Abundance

Non-native species distribution and abundance (*Significance Level*=3) is a management concern within the Bighorn River floodplain in BICA. Changes in vegetation dynamics from flood and fire suppression made the floodplain extremely susceptible to non-native invasions, making the *Condition Level* of this measure a 3. Saltcedar and Russian olive are two of the predominant invaders in the floodplain and persist in high abundance today.

Weighted Condition Score

The *Weighted Condition Score* for this component is a 1.00, indicating the condition is of significant concern. Cottonwood-dominated woodlands in BICA were once governed by natural disturbance regimes (e.g., fire, floods, browsing). Since the 1950s, many of these disturbance regimes ceased because of human actions. Today, cottonwood-dominated woodland area in BICA is decreasing and age-class distribution is skewed towards older trees. As older trees continue to die, more opportunities for non-native invasion will occur, which is a concern to park management.



Sources of Expertise

Suzanne Morstead, local naturalist

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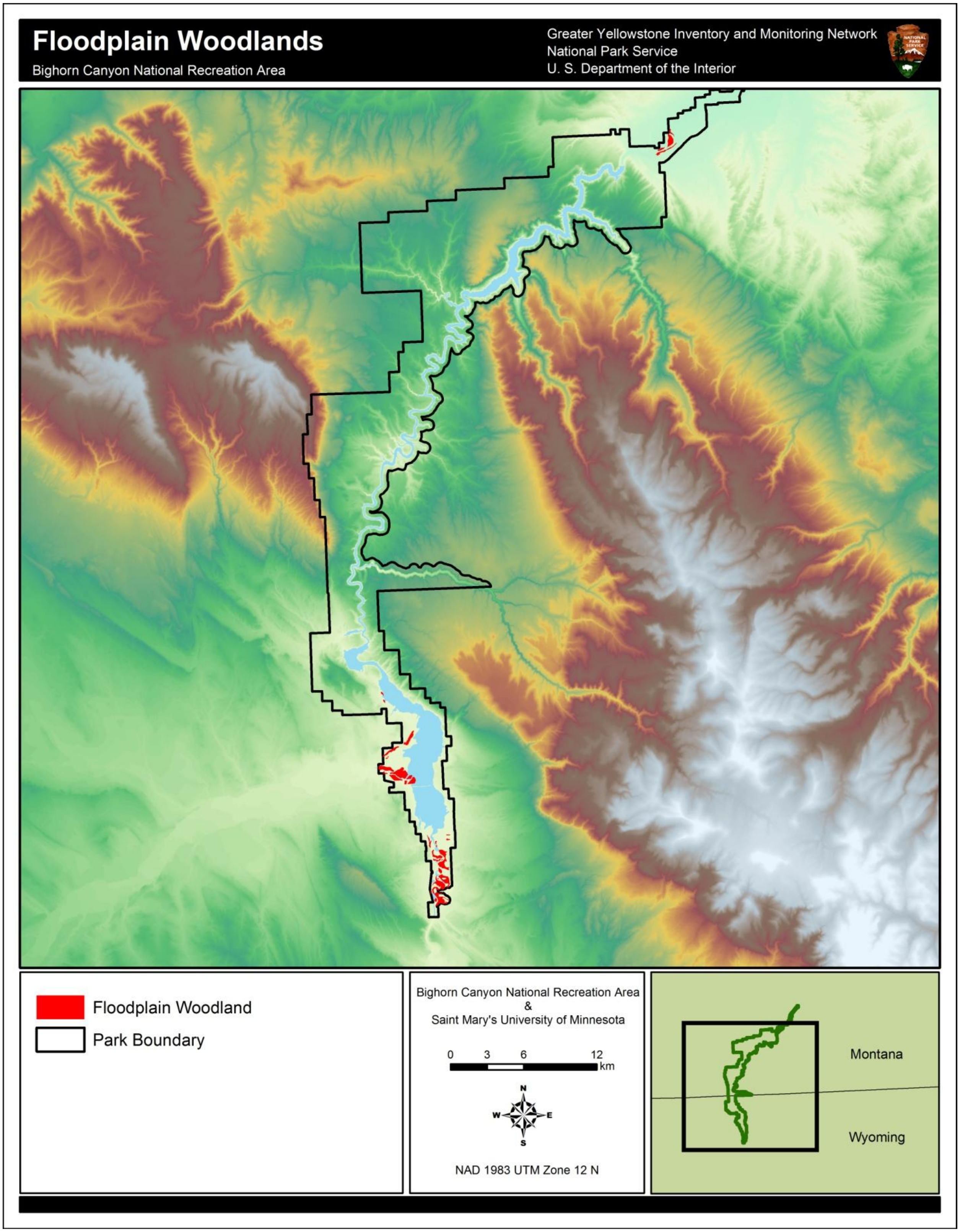

Plate 5. Floodplain woodlands in BICA (NPS n.d.).

4.2 Cushion Plant Community

Description

A cushion plant is a low, woody, plant that forms in pads or mats, with microphyllous foliage, and is often associated with alpine or tundra environments (FGDC 1997). Knight et al. (1987) and DeVelice and Lesica (1993) note that in the BICA area cushion plant communities exist on windswept plateaus, ridges, and foothill slopes. These communities have little total vegetation cover and are made up primarily of cushion-forming perennial forbs (Heidel and Fertig 2000). In BICA, many plants are associated with cushion plant communities, including stemless hymenoxys (*Hymenoxys acaulis*), Hooker's sandwort (*Arenaria hookeri*), musk phlox (*Phlox bryoides*), Bighorn fleabane (*Erigeron allocotus*), rabbit buckwheat (*Eriogonum brevicaule* var. *canum*), and bluebunch wheatgrass (*Pseudoroegneria spicata*) (Heidel and Fertig 2000). Other species that are common and endemic to the Pryor and Bighorn Mountains occur exclusively (or in the highest abundance) in cushion plant communities, such as *Townsendia spathulata* and *Penstemon laricifolius* (Heidel and Fertig 2000). Because cushion plant communities support many rare and endemic plants, they are a management concern for BICA.

Photo 1. Example of a cushion plant community in BICA (courtesy NPS).

Measures

- Species richness and diversity
- Percent coverage of cryptogamic soil
- Total area

Reference Conditions/Values

A reference condition for the cushion plant community in BICA does not exist. Data and literature regarding this resource are sparse. Future monitoring is necessary for defining a reference condition to be used in future assessments.

Data and Methods

BICA and GRYN provided data and literature for this assessment. Additional data and literature searches yielded no relevant information.

Current Condition and Trend

<u>Species Richness and Diversity</u>

Knight et al. (1987) examined the vegetation in BICA in order to develop a vegetation map for BICA. The authors defined three different types of grassland in the park, including windswept plateau, in which the forbs exhibit cushion plant attributes. While Knight et al. (1987) did not provide a detailed inventory of cushion plant species in the park, the species list developed for the windswept plateau community provides a general idea of plants associated with cushion plants in the park at the time of the survey.

Table 5. Species present in the windswept plateau grassland type in BICA; data from three inventory plots examined by Knight et al. 1987. Note that the plant name *Pseudoroegneria spicatus* used by Heidel and Fertig (2000) is a synonym for *Agropyron spicatum*.

	Percent Cover by Plot					Percent Cover by Plot			
Scientific Name	**Plot 5**	**Plot 6**	**Plot 36**	**Mean % Cover**	**Scientific Name**	**Plot 5**	**Plot 6**	**Plot 36**	**Mean % Cover**
Agropyron spicatum	3	4.7	0	2.57	*Ipomopsis pumila*	0.1	0	0	0.03
Arenaria hookeri	3.1	2.8	5.3	3.73	*Juniperus osteosperma*	0	0	0.6	0.20
Aristida fendleriana	1.2	0.1	0	0.43	*Lappula redowskii*	0.1	0	0	0.03
Artemisia frigida	0	0.2	0.1	0.10	*Lesquerella alpina*	0	0	0.2	0.07
Artemisia nova	0.1	0	0	0.03	*Linum lewisii*	0	0	0.1	0.03
Artemisia tridentata	0.8	0	0	0.27	*Lomatium* sp.	0.8	0.1	0.1	0.33
Astragalus spatulatus	0	0.1	0.3	0.13	*Machaeranthera grindelioides*	0.6	0	0	0.20
Atriplex confertifolia	0.1	0.1	0	0.07	*Machaeranthera tanacetifolia*	0	0.7	0	0.23
Carex sp.	0	0	0.1	0.03	*Opuntia polyacantha*	0.3	0.1	0	0.13
Castilleja linearis	0	0	0.2	0.07	*Oxytropus besseyi*	0	0.1	0	0.03
Ceratoides lanata	0.1	0	0	0.03	*Oxytropus* sp.	0.1	0	0	0.03
Chenopodium freemontii	0	0.1	0	0.03	*Paronychia sessiliflora*	0	0	6.9	2.30
Cleome serrulata	0.1	0	0	0.03	*Pediocactus simpsonii*	0.1	0	0	0.03
Cryptantha caespitosa	0	0.1	0	0.03	*Penstemon eriantherus*	0	0	0.1	0.03
Cryptantha celosioides	0.3	1.8	0	0.70	*Phlox bryoides*	1.3	2.1	0	1.13
Cryptantha flavoculata	1	0	0	0.33	*Phlox hoodii*	0.1	0	6.4	2.17
Cryptantha sp.	0	0	0.1	0.03	*Poa sandbergii*	0	0	0.1	0.03
Distichlis stricta	0	0.1	0	0.03	*Sisymbrium linifolium*	0.1	0	0	0.03
Erigeron ochroleucus	0	0	1.1	0.37	*Sphaeralcea coccinea*	0.1	0.1	0	0.07
Eriogonum annum	0.4	0	0	0.13	*Stanleya tornentosa*	0	0	0.1	0.03
Eriogonum brevicaule	0	0.1	0.2	0.10	*Stipa comata*	2.2	0.1	0	0.77
Gaura coccinea	0.1	0.3	0	0.13	*Wyethia scabra*	0.1	0.1	0	0.07
Gutierrezia sarothrae	1.8	1	1.9	1.57	Unknowns (4)	0	0	1.2	0.40
Hymenopappus filifolius	0.5	0.3	0	0.27					
Hymenoxys acaulis	1.2	3.9	1.9	2.33					

Gerhardt (2004) examined the composition of cushion plant communities at two sites in PMWHR (not within BICA boundary) and two sites in BICA. His intention was to determine the effects of grazing on vegetation.

This study examined native plots (void of visible cattle trails), exclosed plots (established in 1992), and grazed plots to help understand the effects that trampling has on cushion plants. Specifically, Gerhardt (2004) examined the difference in presence/absence of four common cushion plant species between plots: *Phlox bryoides*, *Phlox hoodii*, *Leptodactylon caespitosum*, and *Arenaria hookeri*.

For the two plots located in PMWHR, the presence/absence of the four species was similar within and outside of permanent exclosures; *Phlox hoodii* was the only species for which presence/absence differed ($P<0.001$). For the two in-park plots, both *Phlox* species exhibited higher prevalence in the native plots when compared to both the grazed and exclosed plots. When comparing the presence of *Phlox hoodii* between grazed and exclosed plots, no significant differences were evident. Gerhardt (2004, p. 89) concluded that, "There is no evidence that horse grazing is affecting cushion plant frequency/cover based on sampling inside and outside permanent exclosures." Through additional analysis, Gerhardt (2004) also concluded that the negative effects an increasing horse population would have on cushion plants are mitigated during years of increased precipitation.

Heidel and Fertig (2000) indicate that many species associated with cushion plant communities are of conservation concern. Because individual cushion plant communities vary in species composition and abundance, further inventory efforts are needed to understand how species richness and diversity change in relation to different parameters, such as slope, aspect, elevation, and soil properties.

<u>Percent Coverage of Cryptogamic Soil</u>
In BICA, data explaining the percent coverage of cryptogamic soil crusts specific to cushion plant communities are unavailable. However, these crusts are an important piece of the landscape in the park. A cryptogamic soil crust is an association or soil particles, cyanobacteria, algae, microfungi, lichens and bryophytes at the top of a soil horizon (Rosentreter et al. 2007). These crusts exist in arid regions around the world. In arid regions, cryptogamic soil crusts typically dominate all areas not occupied by trees or other vegetation (Rosentreter et al. 2007). These crusts are especially important in arid ecosystems because they provide soil stability and carbon to soils, and produce bio-available nitrogen (Rosentreter et al. 2007).

<u>Total Area</u>
The total area occupied by cushion plant communities is unknown. Knight et al. (1987) found that the windswept plateau community occupied 157 ha (388 ac) of the park at the time of their study. However, since cushion plant communities are often small, the total area is probably larger than the mapped acreage in Knight et al. (1987). Although a new vegetation inventory and mapping is in progress, the updated map is not available for this assessment. No re-classification of landcover in the park has occurred since 1987. Due to the absence of recent data and the fact that cushion plants may not have been specifically mapped in the park, this measure cannot be evaluated.

Threats and Stressor Factors

BICA staff identified grazing and trampling by cattle and horses as potential threats to the cushion plant community in the park. Heidel and Fertig (2000) also indicate that concentrated trampling and degradation could alter cushion plant communities, even though they are located in rugged and remote areas. Given the sensitivity of these communities and the presence of large herbivores in the park, changes in populations of various species (e.g., horses, bighorn sheep, and deer) could have negative effects on cushion plant communities.

Heidel and Fertig (2000) note that non-native species, such as Russian and spotted knapweed (*Acroptilon repens* and *Centaurea stoebe*) and leafy spurge (*Euphorbia esula*), have the potential to alter habitats of rare species across Bighorn Canyon. Cheat grass (*Bromus tectorum*) is another species of concern in BICA (C. Bromley, pers. comm., 2012). Invasions are likely to occur in areas of high human use (e.g., campgrounds, boat landings, and roadsides). If not actively managed, non-native species could spread quickly into cushion plant communities and alter the composition of the communities, thus impacting the rare species that inhabit them. Heidel and Fertig (2000) also note that certain native species, such as purple threeawn (*Aristida purpurea*), increase in abundance during disturbance. With increased grazing pressure, some native species could cause a reduction in the prevalence of cushion plant communities.

Suzanne Morstad, a local naturalist, indicated that *Halogeton glomeratus* is another invasive plant of particular concern regarding the cushion plant community (pers. comm., 2012). *Halogeton* thrives in desert soils, is alkali tolerant, and produces seeds viable for greater than 15 years (S. Morstad, pers. comm., 2012). Currently, the plant is present along roads and railroad tracks in the area and is established along Sykes Mountain, but no widespread infestations are known to exist.

Data Needs/Gaps

Data needs exist for all of the measures of this component. Species richness and diversity are described fairly well for cushion plants as a whole, but little is known about how species richness and diversity vary between different community locations in the park. Understanding the reasons for different assemblages of cushion plant communities could help the process of identifying areas in BICA of particular management concern.

There are minimal data about the total area of cushion plant communities in BICA. Knight et al. (1987) mapped the wind-swept plateau communities, which included plant species associated with cushion plant communities. However, a detailed dataset that describes the location and extent of all cushion plant communities in the park does not exist. Developing data that address this gap in knowledge would be difficult without sufficient time and resources.

Data and information regarding cryptogamic soils is only present in the form of local, expert knowledge. Because data do not exist in a readily accessible form, assessing condition based on this measure is difficult.

Overall Condition

Species Richness and Diversity

The project team defined the *Significance Level* for species richness and diversity as a 3. While sources for information regarding this measure exist, they are dated or not specific enough to allow for assignment of condition.

Percent Coverage of Cryptogamic Soil
A *Significance Level* of 3 was assigned for the measure of percent coverage of cryptogamic soil. Little is known about the percent coverage of cryptogamic soil within the park or the cushion plant communities in the park. Therefore, condition cannot be determined.

Total Area
A *Significance Level* of 2 was assigned for the measure of total area. Only one vegetation map provides an indication of total area of cushion plant communities in the park (Knight et al. 1987). Since no recent data describing cushion plant communities are available to compare with the data Knight et al. (1987) developed, condition for this measure is unknown.

Weighted Condition Score
Due to the lack of recent data and literature regarding the cushion plant communities in BICA, the *Weighted Condition Score* for this component is undefined.

Cushion Plant Community

Measures	SL	CL
• Species richness and diversity	3	n/a
• Percent coverage of cryptogamic soil	3	n/a
• Total area	3	n/a

WCS = N/A

Sources of Expertise
Suzanne Morstad, local naturalist

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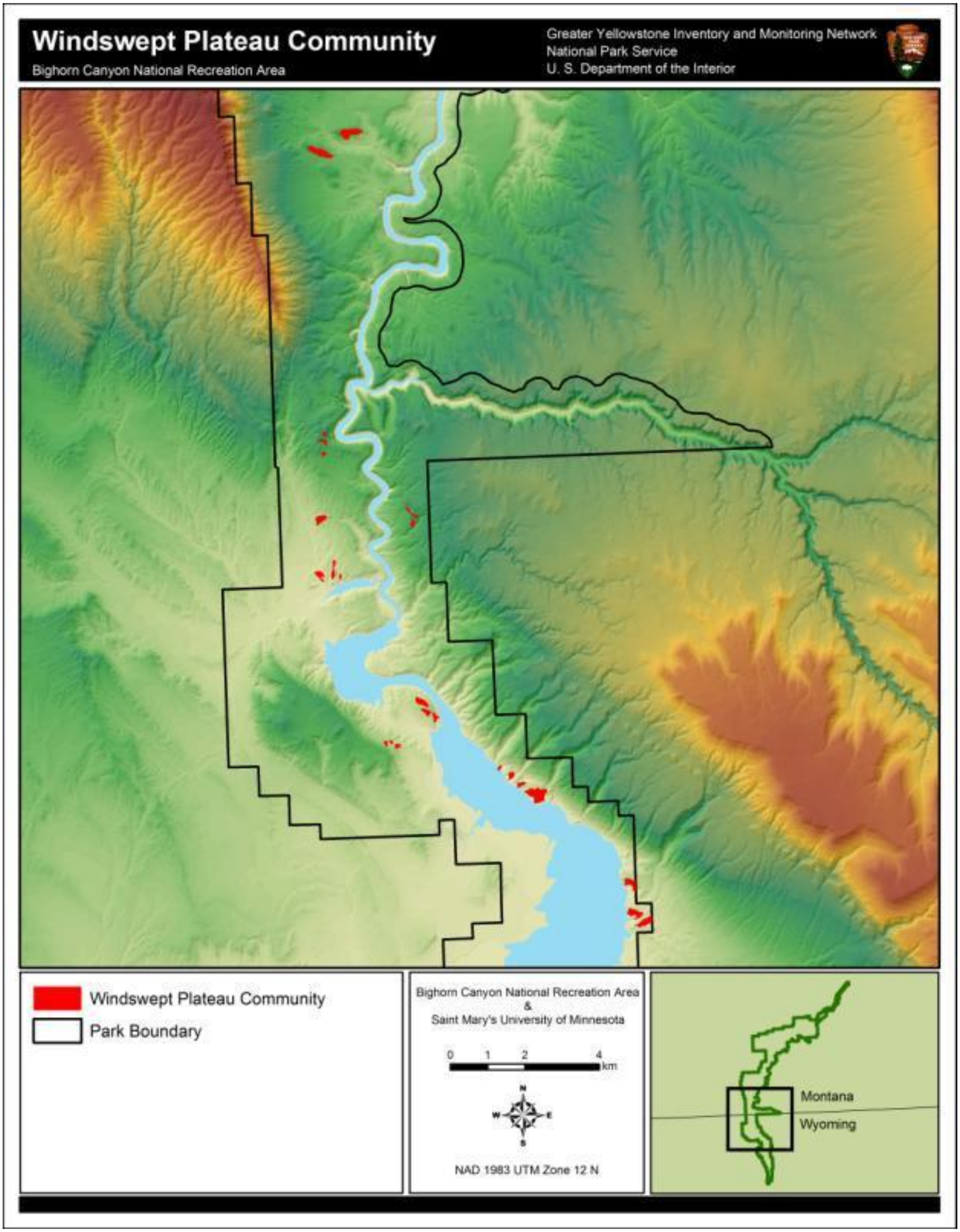


Plate 6. Windswept plateau community as identified by Knight et al. (1987).

4.3 Sagebrush Steppe Community

Description

Sagebrush steppe occupies roughly 12% of the total area in BICA and occurs between 1,200-1,600 m (3,960-5,280 ft) of elevation (Knight et al. 1987; Plate 7). Sagebrush steppe is most prevalent in the central third of the park, north of Lovell, WY. Two major subtypes of the sagebrush steppe community occur in BICA and are characterized according to dominant species: Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) and black sagebrush (*Artemisia nova*) (Knight et al. 1987). Knight et al. (1987) concluded that black sagebrush steppe is the predominant type in the park and is most prevalent at higher elevations within the community's range. DeVelice and Lesica (1993) described the black sagebrush steppe community as common on ridgetops and often adjacent to Utah juniper (*Juniperus osteosperma*) and limber pine (*Pinus flexilis*). Big sagebrush is more prevalent in areas that have soils with higher infiltration rates (Knight et al. 1987).

Measures

- Species richness and diversity
- Encroachment of juniper into sagebrush steppe
- Proportion of native to non-native species
- Relative abundance of protected vs. bare ground

Reference Conditions/Values

Long-term data that are applicable to reference condition do not exist for this component. A recent study (Tercek 2012) resampled vegetation in areas previously sampled in the mid-1980s; this provides some insight into changes in vegetation dynamics in specific upland communities, such as sagebrush steppe. However, a focused reference condition for each of the measures does not exist. BICA and GRYN staff are developing a protocol for monitoring upland vegetation in all parks within GRYN and future assessments should use data acquired according to the protocol to define a sound reference condition.

Data and Methods

Knight et al. (1987) surveyed 15 sagebrush steppe community stands in BICA between 1984 and1986; this provided baseline data for future comparison. Tercek (2012), using Knight et al. (1987) data, established monitoring plots for undisturbed sagebrush steppe communities within BICA. Tercek's data do not allow for a direct, data-based comparison to Knight et al. (1987) data, but some inferences can be made between the two documents.

Current Condition and Trend

<u>Species Richness and Diversity</u>

Within the black sagebrush steppe subtype, black sagebrush is the primary plant species based on mean percent cover (Knight et al. 1987). Similarly, big sagebrush steppe is the dominant plant species in the big sagebrush subtype. Composition of non-dominant plants also varies between the two subtypes; June grass (*Koeleria macrantha*) is more prevalent in black sagebrush steppe and blue grama (*Bouteloua gracilis*) and needle and thread (*Hesperostipa comata*) are more common in the big sagebrush subtype (Table 6).

Table 6. Common plant species in two main sagebrush steppe communities and mean percent cover (Knight et al. 1987).

Species	Black Sagebrush Steppe	Big Sagebrush Steppe
Shrubs		
black sagebrush (*Artemisia nova*)	28	<1
big sagebrush (*Artemisia tridentata*)	4	15
broomweed (*Gutierrezia sarothrae*)	2	2
Grasses and sedges		
bluebunch wheatgrass (*Pseudoroegneria spicata*)	3	4
blue grama (*Bouteloua gracilis*)	1	9
threadleaf sedge (*Carex filifolia*)	4	2
junegrass (*Koeleria macrantha*)	5	1
Sandberg bluegrass (*Poa secunda*)	<1	<1
needle and thread (*Hesperostipa comata*)	<1	3
Forbs and low shrubs		
Hooker's sandwort (*Arenaria hookeri*)	1	<1
fringed sagebrush (*Artemisia frigida*)	<1	<1
plains pricklypear (*Opuntia polyacantha*)	<1	<1
Hood's phlox (*Phlox hoodii*)	1	1

Tercek (2012) also inventoried the species and ground cover type present in sagebrush steppe communities within the park. Two sample frames, titled Sage01 and Sage04, represented the sagebrush steppe community in the study. Random quadrats were sampled within each of the sample frames; in Sage01, 100 quadrats were sampled and in Sage04, 50 quadrats were sampled. In the Sage01 sample frame, the cryptobiotic crust/moss/lichen/fungi cover type displayed the highest average percent cover across quadrats. In the Sage04 sample frame, grasses/sedges were the primary cover type. In total, Tercek (2012) identified 14 plants to species and 2 additional genera in the sagebrush sample frames (Table 7). An anomaly exists between Tercek (2012) and Knight et al. (1987) regarding the species of sagebrush observed; Tercek did not identify black sagebrush (only big sagebrush), whereas Knight et al. recognized black sagebrush as the primary sagebrush species in sagebrush steppe communities within the park.

Table 7. Average percent cover within sagebrush steppe community frames from Tercek (2012) BICA vegetation monitoring in 2011.

	Sage01		Sage04	
Cover Type/Species	**Avg. % Cover**	**SD**	**Avg. % Cover**	**SD**
General Cover				
All Grasses / Sedges	7.2	13.2	10.7	10.6
All Shrubs / Trees	6.6	8.9	8.6	15.3
Cryptobiotic Crust / Moss / Lichen / Fungi	9.2	8.3	4.6	9.0
All Forbs	3.7	4.1	3.1	2.9
Bare Ground	4.0	4.5	3.1	3.0
Sedges	0.3	0.8	1.3	1.3
Species Cover				
Utah juniper (*Juniperus osteosperma*)	10.9	19.7	10.3	14.1
bluebunch wheatgrass (*Pseudoroegneria spicata*)	2.4	2.3	3.4	3.6
big sagebrush (*Artemisia tridentata*)	1.7	4.1	2.7	6.8
junegrass (*Koeleria macrantha*)	1.2	1.2	1.9	1.1
Sandberg bluegrass (*Poa secunda*)	1.7	1.2	1.2	1.2
broomweed (*Gutierrezia sarothrae*)	2.4	3.3	1.1	2.6
saltbush spp. (*Atriplex* spp.)	0.2	0.6	1.0	5.3
needle and thread (*Hesperostipa comata* ssp. *comata*)	2.4	8.7	0.5	1.0
Fendler's threeawn (*Aristida purpurea* var. *fendleriana*)	0.2	0.7	0.2	0.7
plains pricklypear (*Opuntia polyacantha*)	0.4	0.9	0.2	0.7
limber pine (*Pinus flexilis*)	0.0	0.0	0.2	0.6
mountain mahogany (*Cercocarpus ledifolius*)	0.4	2.5	0.1	0.4
blue grama (*Bouteloua gracilis*)	0.1	0.5	0.0	0.0
cheatgrass (*Bromus tectorum*)	0.4	2.5	0.0	0.0
western wheatgrass (*Pascopyrum smithii*)	1.0	1.2	0.0	0.0
dropseed species (*Sporobolus* spp.)	0.1	0.4	0.0	0.0

Encroachment of Juniper into Sagebrush Steppe

Waugh (1986) found that many juniper seedlings established under the sagebrush. He hypothesized that the increase in sagebrush prevalence provided an environment suitable for juniper expansion. Today, park staff actively manage against juniper expansion, using fire as a primary tool for removing juniper. However, juniper expansion is still a concern, especially as it relates to forage availability for wildlife species.

In 2011, Tercek (2012) found that juniper abundance in sagebrush steppe communities was higher than anticipated. Knight et al. (1987) found that juniper cover was less than 1% in sagebrush steppe communities within BICA. When Tercek (2012) examined sagebrush steppe communities in BICA, he found that juniper comprised 10-13% cover. Tercek (2012) offered two possible reasons for the difference between 1987 and 2011. First, the actual composition of the sagebrush steppe community may have changed over time. Second, Knight et al. (1987) incorporated more survey areas and it is possible that the 2011 study included a disproportionate number of sagebrush steppe plots with high juniper density when compared to the entire BICA landscape (Tercek 2012).

Proportion of Native to Non-native Species

The invasive species watch list for BICA includes 38 invasive species (Tercek 2012). Of the species on the target list for the park, Tercek (2012) only detected three in his sampling: Japanese brome (*Bromus japonicus*), cheatgrass (*Bromus tectorum*), and halogeton (*Halogeton glomeratus*). However, Tercek's specific intent was not to capture the status of invasive species in the park with his protocol. Both cheatgrass and halogeton are common within portions of the PMWHR, but the literature does not clearly depict the prevalence of these species within sagebrush steppe communities in the park. In the two sagebrush sample frames, cheatgrass was present in less than 5% of plots and halogeton was not present. However, information provided by Tercek (2012) does not provide a holistic representation of non-native species encroachment into sagebrush steppe within BICA. Cassity Bromley (pers. comm., 2012) indicated that many areas of sagebrush steppe within BICA contain high proportions of cheatgrass.

Relative Abundance of Protected vs. Bare Ground

Tercek (2012) found that when compared to juniper mountain mahogany and juniper community types, the sagebrush steppe community exhibited the lowest percent cover of bare ground (Figure 3). Another important resource in BICA is cryptobiotic crusts. Cryptobiotic crusts, including lichen and fungi cover, are living soils (discussed in detail in the Cushion Plant Community section of this report) and could be confused with bare ground by an untrained observer. The Sage01 sample frame exhibited the highest mean percent cover of cryptobiotic crusts of all sample frames examined by Tercek (2012) (Figure 4); every quadrat examined in the Sage01 sample frame in 2011 had cryptobiotic crust. However, the variation across quadrats was high.

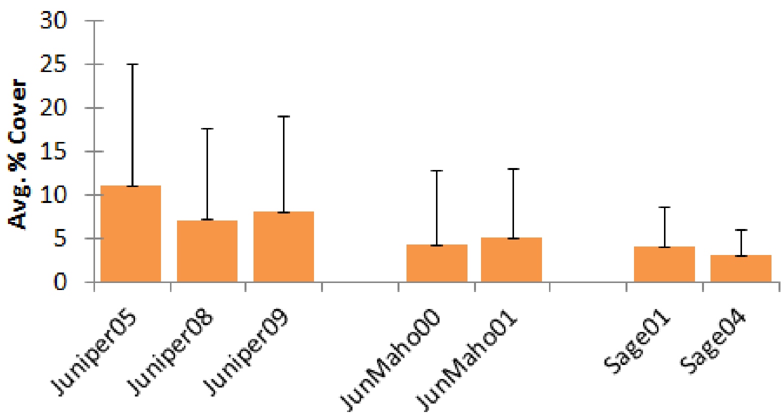


Figure 3. Average percent bare ground cover from Tercek (2012) for all sample frames in BICA.

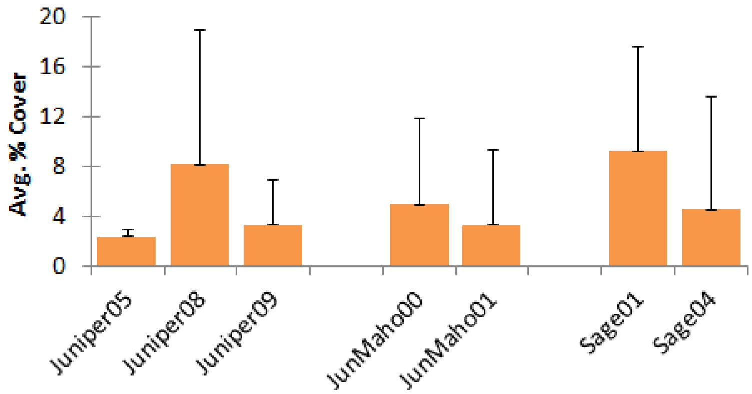


Figure 4. Average percent cryptobiotic/lichen/fungi cover from Tercek (2012) for all sample frames in BICA.

Threats and Stressor Factors

Because the Bighorn basin has a long history of human inhabitance, anthropogenic effects on the vegetation within the basin are numerous. Fire suppression, transportation development, cattle grazing and associated trampling, and irrigation infrastructure are a few causes for vegetation deviating from its presettlement state in the Bighorn basin. Grazing and trampling are two particular stressors BICA staff identified as a threat to the park's sagebrush steppe community. Livestock and wild horse grazing has occurred in the area since the late 1800s (NPS 2009).

Data Needs/Gaps

Once there is a protocol for monitoring upland vegetation, data from subsequent monitoring should provide reference conditions, comparable data, and the ability to identify trends in condition. This protocol is in development, based on information acquired from Tercek (2012) and monitoring performed in other NPS networks.

Overall Condition

Species Richness and Diversity

The project team assigned a *Significance Level* of 3 to the species richness and diversity measure. Two surveys describe the species present in the sagebrush steppe community in BICA: Knight et al. (1987) and Tercek (2012). However, only Knight et al. intended to describe all individual species within the sagebrush steppe community across the whole park. These studies sampled the same areas, but due to the lack of reference condition, the *Condition Level* is unknown.

Encroachment of Juniper into Sagebrush Steppe

The *Significance Level* of this measure is 2. Generally, the expansion of juniper throughout all upland plant communities in the park is a concern to park management because of displacement of other vegetation, mountain mahogany in particular. However, the rate of juniper expansion in the park is unknown. Photo-interpretation or remote sensing could provide data in the future; recently, high-resolution satellite imagery became available for the park. Given that reference condition is unknown and numerical data are unavailable, *Condition Level* for this measure is unknown.

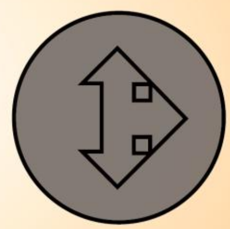
Proportion of Native to Non-native Species
The *Significance Level* of the proportion of native to non-native species measure is 3. Tercek (2012) found few invasive species in the sagebrush steppe quadrats sampled in 2011; he identified only three of the non-native species on the park's watch list across all sample frames. Cheatgrass was the only non-native species found in the sagebrush sample frames and was present in less than 5% of all sagebrush quadrats sampled. However, due to the limited area sampled by Tercek, *Condition Level* for this component is unknown.

Relative Abundance of Protected vs. Bare Ground
The *Significance Level* of the relative abundance of protected vs. bare ground measure is 3. Tercek (2012) provided data regarding this measure for upland vegetation communities across the park. However, Tercek (2012) did not offer specific conclusions regarding the implications of observed percent cover of bare ground within sagebrush steppe communities. Data from Tercek (2012) could be used as a reference condition in the future, but does not lend itself to defining *Condition Level* at this time.

Weighted Condition Score
Because *Condition Level* is unknown for all measures except proportion of native to non-native species, it is not appropriate to define a *Weighted Condition Score* for this resource.

Sagebrush Steppe Community

Measures	SL	CL
Species richness and diversity	3	n/a
Encroachment of juniper into sagebrush steppe	2	n/a
Proportion of native to non-native species	3	n/a
Relative abundance of protected vs. bare ground	3	n/a



WCS = N/A

Sources of Expertise
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Matt Rickets, NRCS Rangeland Management Specialist

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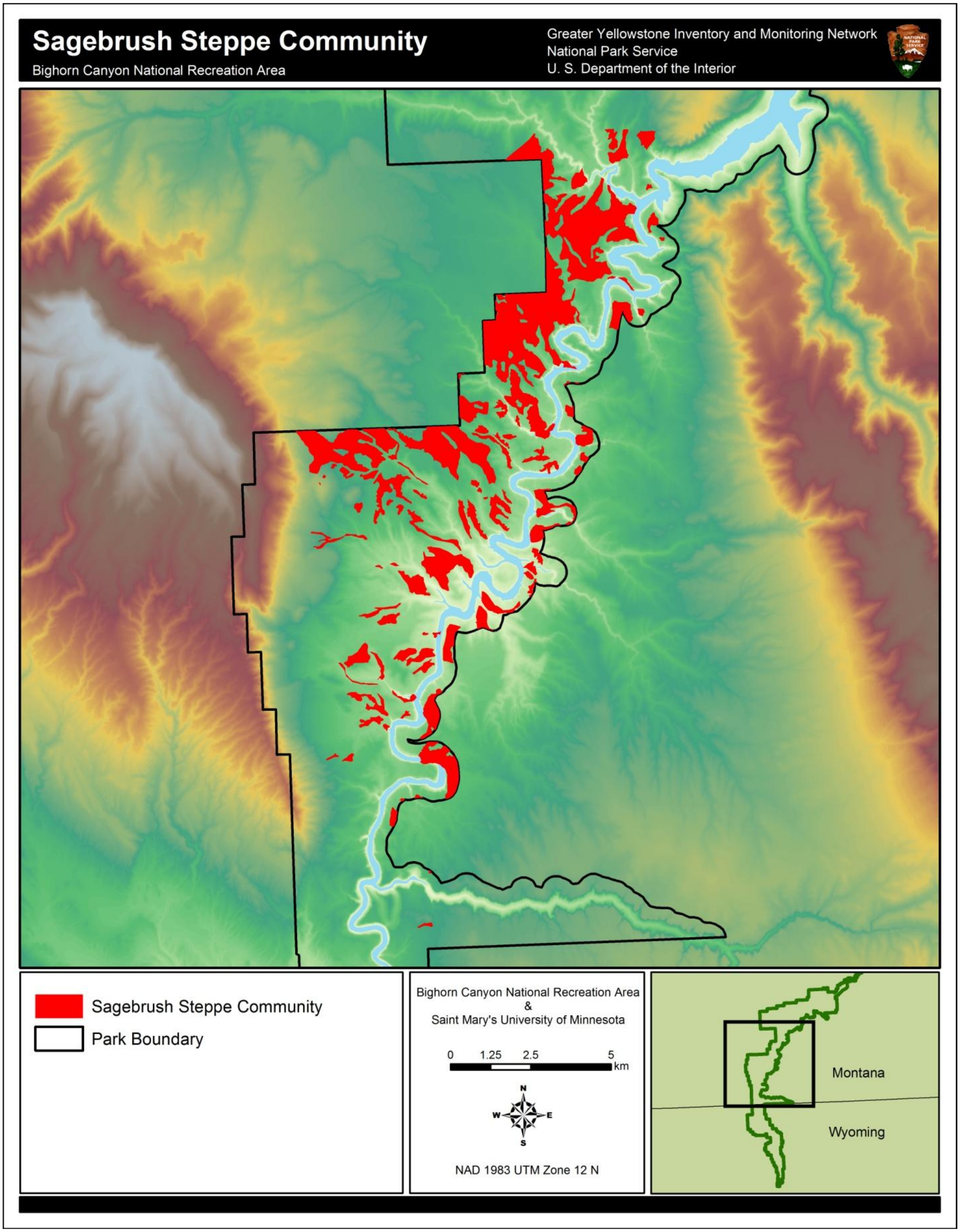

Plate 7. Sagebrush steppe community in BICA (NPS n.d.).

4.4 Juniper, Pine, Mountain Mahogany Community

Description

The juniper, pine, and mountain mahogany community is the most widespread vegetation community at BICA, and is dominated by the Utah juniper and the curlleaf mountain mahogany (*Cercocarpus ledifolius*) (Photo 2) (Knight et al. 1987). Two pine species, the limber pine and ponderosa pine (*Pinus ponderosa*) (Photo 2), also make up this community and are intermittently found, generally in areas with higher precipitation. Mountain mahogany, a primary shrub species in this community, is an important food source for bighorn sheep (*Ovis canadensis*) during winter and the community as a whole provides important habitat for ungulates; BLM (2009) states that this community is important within the PMWHR because it provides a primary wintering habitat for mule deer (*Odocoileus hemionus*). Hence, GRYN identified the juniper, pine, and mountain mahogany woodlands as a potential Vital Sign for all parks in the network during the planning process, because it is an indicator of overall system health (Ricketts et al. 2004, Jean et al 2005)

Photo 2. Utah juniper (top left), curlleaf mountain mahogany (top right), limber pine (bottom left), and ponderosa pine (bottom right) (NPS photos).

The Pryor Mountain Desert creates a unique biological landscape that contains many examples of rare and endemic vegetation (DeVelice and Lesica 1993). Juniper and mountain mahogany woodlands occur on shallow soils or fractured bedrock and are characteristic of northern Wyoming and southcentral Montana (Wight and Fisser 1968, Knight et al. 1987, NPS 2010). A consensus regarding the exact elevation where this community occurs does not exist; various sources describe the community occurring anywhere between 1,134 and 1,981 meters (3,720 and 6,500 feet) in elevation (Wight and Fisser 1968, Knight et al. 1987, DeVelice and Lesica 1993, NPS 2010). Limestone and sandstone are the primary bedrock types for this community, as these often-fractured bedrocks funnel rainfall and snowmelt to provide the primary water source for vegetation (Knight et al. 1987).

Juniper occur on the landscape alongside mountain mahogany but have increased in density in recent years (due mainly to fire suppression), choking out mountain mahogany and reducing prime habitat for bighorn sheep. Possible drivers for this landscape change include climate change and grazing (C. Bromley, pers. comm., 2012).

Measures

- Total area
- Recruitment of mountain mahogany
- Percent native to non-native species
- Species diversity and presence/absence of pine
- Juniper density

Reference Conditions/Values

The most recent available study examining current condition of juniper, pine, and mountain mahogany communities is Tercek (2012), which draws comparisons to the study by Knight et al. (1987). As current available literature does not allow for direct quantifiable comparison between studies, common trends in data and literature presented by Tercek (2012) were used as a benchmark to determine overall condition. Because quantifiable data is lacking for several measures, conclusions are only drawn for measures where condition is clearly identifiable.

Data and Methods

Knight et al. (1987) surveyed 31 juniper and mountain mahogany woodland stands within BICA between 1984 and 1986. This provided much of the baseline community composition data for juniper, pine, and mahogany woodlands in the park.

In 2002, Gerhardt (2004) established a large permanent exclosure network in the Pryor Mountain Wild Horse Range (PMWHR) and BICA to monitor the effects of grazing by large herbivores and different vegetation management practices on plant communities. Sampling occurred at locations previously sampled from 1992 to 1996 in order to continue vegetation monitoring at established exclosure locations. The Gerhardt (2004) report provides results from the study, as well as reviews of relevant findings from prior studies.

The NPS (2009) developed a fire management plan outlining the policies that drive management decisions in BICA. Fire suppression is one of the main drivers of juniper encroachment and has become an important topic in recent years. These policies are important for the management of fire events, development of strategies, and general guidance regarding fire events in the juniper, pine, and mountain mahogany community.

Tercek (2012) monitored different elements of juniper and mountain mahogany plant species within BICA including extent, condition, and invasion of non-native species. Tercek (2012) draws several comparisons between the study by Knight et al. (1987) and the current plant community dynamics of BICA.

Current Condition and Trend

<u>Total Area</u>

Knight et al. (1987) examined the land cover within BICA during the mid-1980s. They found that juniper and mountain mahogany woodlands covered 8,909 ha (22,015 acres), or 40% of the land area in BICA at that time. This community occurred primarily in the central one-third of BICA (Knight et al. 1987, Plate 8). Knight et al. (1987) subdivided the juniper and mountain mahogany woodland land cover into three smaller classifications based on the dominant species in the area: mountain mahogany shrubland (652 ha), juniper woodland (6,502 ha), and juniper and mountain mahogany woodland (1,755 ha). Knight et al. (1987) also mention that vegetation cover is generally low and that juniper distributions are discontinuous in juniper and mountain mahogany woodlands. Distributions of limber and ponderosa pine are infrequent and intermittently dispersed throughout the park. Plate 8 displays the extent of juniper and mountain mahogany woodland, mountain mahogany shrubland, and limber and ponderosa pine community distributions within BICA (NPS n.d.).

<u>Recruitment of Mountain Mahogany</u>

Gerhardt (2004) measured recruitment of curlleaf mountain mahogany shrubs at two sites in BICA: Bat Cave and Yellow Hill. Current annual growth (CAG) twigs were estimated and then counted for small (<10 cm tall), medium (>10 cm, <40 cm), and large (>40 cm) shrubs. According to Gerhardt (2004, p. 80), "shrub size had significant effects on number of CAG twigs, mean CAG mass, and CAG production/shrub." Both sites showed similar mountain mahogany shrub production.

According to NPS (2009), the majority of fires within BICA occur in the juniper and mountain mahogany woodlands, leading to increased mortality of mountain mahogany. Mountain mahogany is a preferred plant type of bighorn sheep and deer species, which spend much of their time feeding on this species, with seasonal variation (Gerhardt 2004). Furthermore, browsing pressure by cattle, horses, and other large mammal species in BICA limit overall recruitment of mountain mahogany, possibly allowing for spatial shifts. Germination rates of mountain mahogany generally decrease in response to heat but seedlings are known to appear in early post-fire communities. Recently, long-term drought may have contributed to a mortality event within the park (C. Bromley, pers. comm., 2012). However, the recruitment of new mountain mahogany shrubs may require a fire-free interval of 100 years or more in western states (Keeley 1987).

<u>Percent Native to Non-native Species</u>

The invasive species watch list for BICA includes 38 invasive species (Tercek 2012). Tercek (2012) detected only three species during sampling: Japanese brome, cheatgrass, and halogeton. Both cheatgrass and halogeton are common within portions of the PMWHR, but the literature does not clearly depict the prevalence of these species within the juniper and mountain mahogany community. Areas within the NPS-managed segment of the PMWHR indicate severe habitat degradation by species such as cheatgrass (Ricketts et al. 1987, as cited in Tercek 2012). Ricketts et al. (2004, as cited in Tercek 2012, p. 2) notes that "the [NPS] portion of the PMWHR had only 44% similarity to baseline data collected in 1981, and that 67% of the plant communities surveyed were in a 'downward trend.'" Tercek (2012) noted that cheatgrass appeared in nearly all of the sample frames but in only a small fraction of plots (1-2%) (Figure 5). Overall percent cover was less than 1%. Halogeton was found in two juniper and mountain mahogany frames where it was found in 1% and 13% of the plots respectively (Tercek 2012) (Figure 5). Halogeton represented less than 1% of the total cover (Always in the 1-5% cover class) (Tercek 2012). Only one instance of Japanese brome was identified in the juniper plant community, representing a small infestation (Tercek 2012). Tercek (2012) also noted that the field crew observed several small areas containing cheatgrass and halogeton.

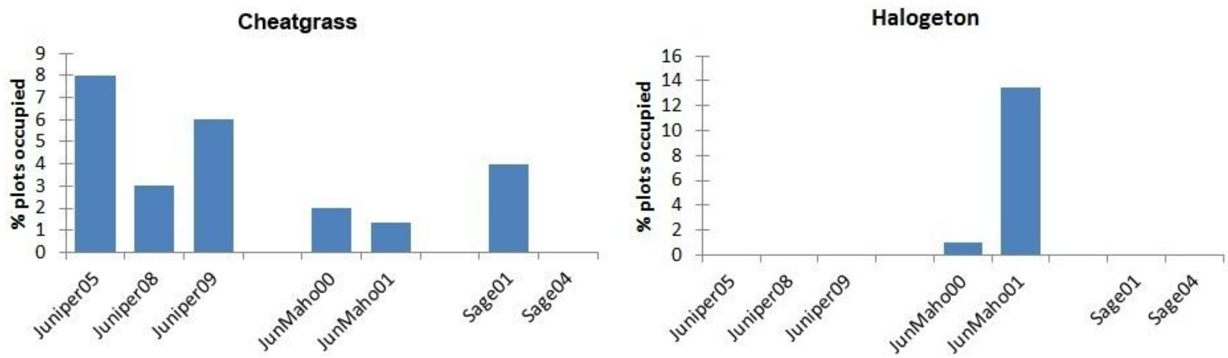

Figure 5. Percentage of plots occupied by cheatgrass and halogeton in the Tercek (2012) study. Juniper and mountain mahogany plant community frames are represented by the labels “JunMaho00” and “JunMaho01.”

<u>Species Diversity and Presence/Absence of Pine</u>

Several species are associated with Utah juniper and curlleaf mountain mahogany in the juniper and mountain mahogany woodland: black sagebrush, broom snakeweed (*Gutierrezia sarothrae*), bluebunch wheatgrass, Fendler threeawn (*Aristida purpurea*), limber pine, and Rocky Mountain juniper (*Juniperus scopulorum*). Table 8 displays common plant species in the juniper and mountain mahogany woodland community. Knight et al. (1987) note that the rich diversity of plant species in BICA is due to factors such as elevation, water availability, temperature inversions, fire frequency, and grazing intensity, among others.

Limber and ponderosa pine, found intermittently throughout the juniper and mountain mahogany woodlands, are unique staples of the northern BICA subalpine range. Limber pine, which is a food source for birds and small mammal species (C. Bromley, pers. comm., 2012), exists in the southern portion of BICA and at higher elevations than juniper and mountain mahogany (Knight et al. 1987). The ponderosa pine is generally found in wider portions of the Bighorn Canyon, north of the monocline, but at lower elevations; it requires greater rainfall during growing seasons (Knight et al. 1987). Populations of both species are often scattered and found dispersed between other plant communities as well, such as Douglas-fir (*Pseudotsuga menziesii*) and juniper and mountain mahogany woodlands (Knight et al. 1987). Knight et al. (1987) noted that the area contained rich and diversified plant communities. Plate 8 displays limber and ponderosa pine distributions in BICA.

Table 8. Common plant species in juniper woodland, juniper and mountain mahogany community, and mountain mahogany shrubland community within BICA (Knight et al. 1987).

Scientific Name	Common Name
Agropyron spicatum	bluebunch wheatgrass
Arenaria hookeri	Hooker's sandwort
Aristida fendleriana	Fendler's threeawn
Artemisia frigida	fringed sagebrush
Artemisia nova	black sagebrush
Artemisia tridentata	big sagebrush
Bouteloua gracilis	blue grama
Ceratoides lanata	winterfat
Cercocarpus ledifolius	curlleaf mountain mahogany
Cryptantha flavoculata	roughseed catseye
Erigeron spp.	fleabane
Eriogonum spp.	buckwheat
Gutierrezia sarothrae	broom snakeweed
Hymenoxys acaulis	sundancer daisy
Juniperus osteosperma	Utah juniper
Juniperus scopulorum	Rocky Mountain juniper
Lappula redowskii	stickweed
Lepidium densiflorum	common pepperweed
Opuntia polyacantha	plains pricklypear
Oryzopsis hymenoides	Indian ricegrass
Paronychia sessiliflora	creeping nailwort
Pinus flexilis	limber pine
Rhus trilobata	skunkbush sumac
Stipa comata	needle and thread grass
Tanacetum capitatum	rock tansy

Juniper Density

Very little information is available for juniper densities within BICA beyond the initial Knight et al. (1987) vegetation study. The NPS (2009) notes that juniper communities have significantly spread in range since settlement of the western United States through vectors such as overgrazing, fire exclusion, dispersion of seed, or a combination of several factors. Anecdotal evidence suggests that densities of juniper within BICA have increased since the 1987 baseline study by Knight et al. (1987). Knight et al. (1987) note that, while examination of juniper expansion was not the intent of the 1987 study, this occurrence was seen in other portions of the Bighorn Basin as well. Tercek (2012) suggests possible changes in vegetation since the study by Knight et al. (1987) based on 2011 field observations, possibly due to differences in sample frames. Plate 8 shows distributions of juniper in BICA, highlighting areas of higher densities.

SMUMN GSS (2012) analyzed juniper density within the three juniper sample frames examined by Tercek (2012) using photo interpretation of 2011 0.5-m resolution GeoEye Imagery and quadrat sampling data from Tercek (2012); quadrat data were acquired within one month of the date of the imagery. The dominant cover class within sample frame 5 was 20-40% (59% total frame area); the 40-60% class was dominant in sample frames 8 and 9, at 54% and 63% of total frame area, respectively (Table 9).

Table 9. 2011 Percent juniper cover for juniper sample frames from Tercek (2012) (SMUMN GSS 2012).

	Frame 5		Frame 8		Frame 9	
% Juniper Cover	Acres	% Frame Area	Acres	% Frame Area	Acres	% Frame Area
None	20.9	18%	37.8	20%	7.3	7%
0%-20%	24.3	21%	15.4	8%	11.7	12%
20%-40%	59.6	51%	15.5	8%	16.9	17%
40%-60%	8.4	7%	102.9	54%	63.5	63%
60%-80%	0.7	1%	18.2	10%	1.3	1%
80%-100%	2.1	2%	0.0	0%	0.0	0%
Total	115.9		189.9		100.7	

Threats and Stressor Factors

Juniper encroachment into treeless plant communities is an important environmental change that has taken place over the past few decades (Sankey and Germino 2008). According to Sankey and Germino (2008), the encroachment rate of juniper between 1985 and 2005 in southeastern Idaho, west of BICA, was approximately 22-30%. The NPS (2009) also notes that juniper woodlands have greatly expanded their range in the mountainous west; this spread is attributed to overgrazing, fire suppression, and seed dispersal by livestock. Lack of fire/fire suppression often creates favorable conditions for juniper expansion into grasslands and, according to Knight et al. (1987), the change of grassland to sagebrush and then to juniper woodland may be accelerated due directly to fire suppression. The fire-return interval for juniper woodlands is 30-50 years (NPS 2009), whereas germination rates of mountain mahogany generally decrease in response to fire, resulting in nearly a 100-year fire interval for true mountain mahogany (Keeley 1986). Aerial fuels, such as juniper and mountain mahogany, are sources commonly consumed by prescribed fires in the Pryor Mountain and Canyon Units of BICA to maintain landscapes and improve habitat since they comprise the largest plant community in these areas (NPS 2009). Knight et al. (1987, p. 44) suggested using prescribed fires in juniper and mountain mahogany woodlands in accordance with management objectives, noting that "juniper is more capable than mountain mahogany of invading adjacent rangelands on deeper soils," which has lead to extensive tracts of land in the Bighorn Basin being dominated by Utah juniper. Fire, directly or indirectly, contributed to regulating the distribution of juniper as young junipers are susceptible to fire until they reach heights of three or four feet; however, juniper spacing and the absence of fine fuels generally restrict juniper suppression unless each tree is ignited individually (Knight et al. 1987, NPS 2009). If the grass understory has been eliminated or reduced through grazing, fire will not occur to the same extent or intensity across the landscape and, with more of the area covered by juniper, grasses and forbs are less able to compete for water, light, nutrients, etc. (Knight et al. 1987, NPS 2010). Tausch and Tueller (1977) have proposed that fire intervals of 50-60 years could help prevent juniper invasion by keeping populations in check and juniper densities within allowable limits. However, it is unknown whether reduction of juniper could have negative effects on feral horse, deer, and wildlife populations by eliminating cover and shade habitat. Recently, sheep use of burned areas has increased due to removal of juniper and elimination of predator hiding cover (C. Bromley, pers. comm., 2012).

Grazing pressure on mountain mahogany and encroachment of juniper remains a major ecological topic of interest in the intermountain west (Knight et al. 1987). Juniper woodlands are thought to be spreading and encroaching on adjacent grass and shrubland, compromising bighorn sheep habitat (Knight et al. 1987). Waugh (1986, as cited in Knight et al. 1987) showed that 90% of the juniper seedlings were becoming established under sagebrush, possibly being used as nurse plants. Waugh (1986, as cited in Knight et al. 1987, p. 46) hypothesized that "the increases of sagebrush following livestock grazing had created a more favorable environment for juniper invasion." Junipers are also extremely resistant to drought and they form a ring of nutrient depleted soil that inhibits nearby plant growth (NPS 2010). They compete with native grasses and often spread to adjacent grasslands or shrublands, choking out these plant communities. Added forage pressure on curlleaf mountain mahogany from species such as bighorn sheep and deer may also be contributing to encroachment of juniper on mountain mahogany communities as, according to Kissel (1996, as cited in Gerhardt 2004), curlleaf mountain mahogany accounted for nearly 66% of the yearly BICA deer diet. In the study by Sankey and Germino (2008), juniper encroachment was found to be significantly higher in areas of ungulate grazing, suggesting that browsing pressure is likely limiting recruitment of mountain mahogany and promoting juniper encroachment, allowing for species shifts.

Generally, control of non-native plant invasions is a common yet difficult goal to achieve (Knight et al. 1987). Non-native and invasive plant species contribute a major stress to the juniper, pine, and mountain mahogany community in BICA. Invasions of non-native plants are facilitated by several different vectors including human introductions, and by cattle and bird species (Knight et al. 1987). Reservoirs and roadways, generally areas with high anthropogenic influence, are the most common sites of introduction. Species confirmed within the park were Russian thistle (*Kali tragus*), Canada thistle (*Cirsium arvense*), leafy spurge, Russian knapweed, and hoary cress (*Cardaria draba*) (Knight et al. 1987). However, none of these species were found within the randomly surveyed locations in the more recent study by Tercek (2012). Knight et al. (1987) note that abundant weed occurrences have resulted in reductions in native plant species abundance through direct competition for resources. It is hypothesized that certain invasive species increase flammability and/or fire frequency. One particular invasive species of concern in BICA is halogeton because of its excretion of salts, making it difficult for other plants to grow (Tercek 2012). Generally, cheatgrass and Japanese brome increase following fire events and are species worthy of continued monitoring (Jean, pers. comm., 2011). Both are annuals that germinate early in the spring and drop seed quickly, forcing out native plants if conditions are favorable (Jean, pers. comm., 2011).

Limber pine is susceptible to rust disease that is prevalent in western states; however, it is unknown whether rust disease is periodically present within BICA (Jean, pers. comm., 2011). Epidemic insect species threatening limber pine include the mountain pine/bark beetle (*Dendroctonus ponderosae*), which is responsible for some mortality currently occurring in BICA (Knight et al. 1987; Jean, pers. comm., 2011).

Data Needs/Gaps

More recent land cover and vegetation evaluations would be helpful to better assess the extent of the juniper, pine, and mountain mahogany community. The most recent land cover and plant community evaluations come from Knight et al. (1987), which are now over 25 years old. An NPS Vegetation Inventory is underway at BICA and will provide a map of current vegetation within the park (Jean, pers. comm., 2012). Studies analyzing changes in plant community composition would help to further evaluate several measures, specifically juniper density and percent native to non-native species. Reevaluation of the Knight et al. (1987) study area could show changes in native plant communities within the past 25 years while providing more recent data from which to better assess condition However, data do not allow for a direct, data-based comparison to Knight et al. (1987) data. Some inferences can be made between the two documents.

Studies analyzing juniper encroachment in BICA would help in assessing overall condition. Currently, there are few sources that directly deal with invasion of juniper within BICA. There have not been any studies since the 1992-1994 Gerhardt (2004) study to determine recruitment rates of mountain mahogany in BICA or the PMWHR, and overall little information exists about recruitment rates for mountain mahogany. Further studies of the BICA juniper, pine, and mountain mahogany community, including the long term monitoring planned by the GRYN should prove beneficial to future condition assessments.

Recently, high-resolution infrared satellite imagery became available for BICA. The satellite imagery is 0.5-m^2 resolution. This imagery could be used to develop data explaining the density of juniper in the park, which is currently unknown. These data could then provide a benchmark for future comparison, if additional imagery of comparable quality is available in the future.

Overall Condition

Total Area

A *Significance Level* of 2 was assigned to the measure of total area by BICA staff. Total area was not assigned a *Condition Level* due to the lack of a reference condition. The reference condition for total area was not quantified for woodlands; therefore, no condition level can currently be assigned to this measure.

Recruitment of Mountain Mahogany

A *Significance Level* of 3 was assigned to the measure of recruitment of mountain mahogany by BICA staff. Due to the lack of information and data regarding this measure, it is not possible to evaluate or assign a *Condition Level* for recruitment of mountain mahogany at this time.

Percent Native to Non-Native Species

A *Significance Level* of 2 was assigned to the measure of percent native to non-native species by BICA staff. A *Condition Level* of 1 was assigned to this measure, as it is currently of low concern in woodland communities to resource managers, indicating only slight signs of impairment and degradation. Invasions of non-native species appear to be relatively minor, with cheatgrass being the only widely occurring species. The study by Tercek (2012) showed that only a small percentage of surveyed plots exhibited infestation. Cheatgrass infestation was observed throughout the juniper and mountain mahogany plant community, whereas only localized areas of halogeton were found. Tercek (2012) suggested continued sampling in new frames, as well as re-sampling of 2011 plots to measure year-to-year variability.

Species Diversity and Presence/Absence of Pine

A *Significance Level* of 2 was assigned to the measure of species diversity and presence/absence of pine by BICA staff. A *Condition Level* of 1 was assigned to this measure, indicating it is currently of low concern to resource managers. Intermittent distributions of limber and ponderosa pine within BICA are endemic to the ecological region, with factors such as water availability, rainfall, fire frequency, and grazing intensity influencing the distribution of pine species. Knight et al. (1987, p. 57) noted “a rich diversity of vegetation in the area.” Rust disease is currently unconfirmed in BICA limber pine. Recent pine mortalities will likely continue, indicating an area of concern to resource managers.

Juniper Density

A *Significance Level* of 3 was assigned to the measure of juniper density by BICA staff. Due to the lack of information and data regarding this measure, it is not possible to evaluate or assign a *Condition Level* at this time. Juniper density information is severely lacking and densities of juniper have not been reported since the Knight et al. (1987) study. While increasing juniper occurrence is seen in other portions of the Big Horn Basin, little information exists, with no quantifiable density data within BICA.

Weighted Condition Score

The overall *Weighted Condition Score* (WCS) for the BICA juniper, pine, mountain mahogany community was not assigned. Due to the lack of information and data, it was not possible to calculate an overall condition score, since more than half of the measures did not receive a *Condition Level*.

Juniper, Pine, Mountain Mahogany Community

Measures	SL	CL
• Total Area	2	N/A
• Recruitment of Mountain Mahogany	3	N/A
• Percent Native to Non-Native Species	2	1
• Species Diversity and Presence/Absence of Pine	2	1
• Juniper Density	3	N/A

WCS = N/A

Sources of Expertise

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Cassity Bromley, BICA Chief of Resources.

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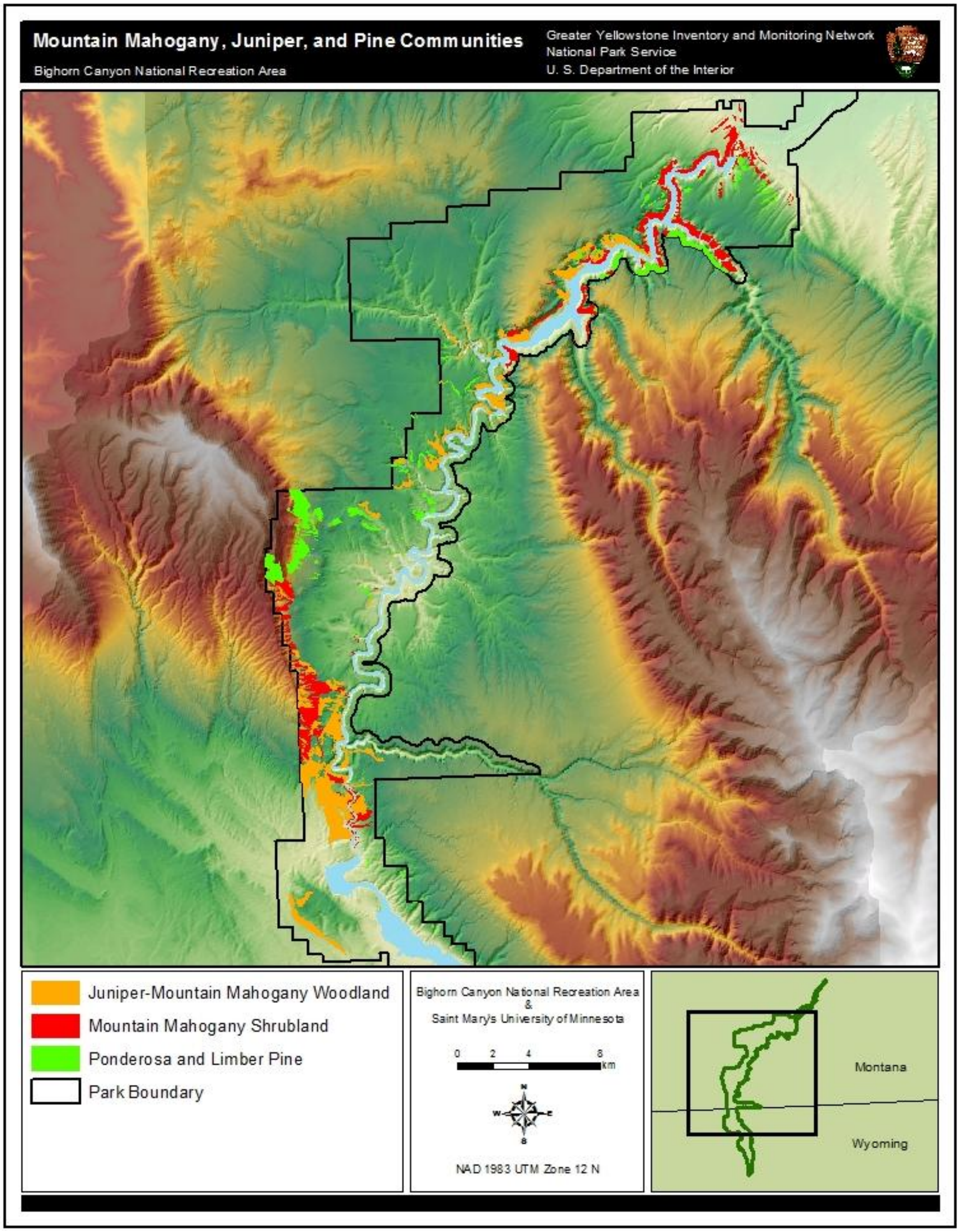

Plate 8. Juniper, pine and mountain mahogany communities in BICA (NPS n.d.).

4.5 Bighorn Sheep

Description

Photo 3. Bighorn sheep in the south unit of BICA (NPS photo by Henthorne).

Bighorn sheep (*Ovis canadensis*) were extirpated from the Pryor Mountains area in the 1800s (NPS 2010) and reappeared in BICA after a reintroduction effort in 1973 (Singer and Schoenecker 2004). The population peaked at approximately 211 sheep in 1993-1994; a rapid decline followed in 1995 and 1996, leaving the post-1998 population at approximately 80-120 sheep (Singer and Schoenecker 2004). The exact causes of this rapid decline are unknown, but disease, an exceedance of their carrying capacity, predation, and competition with wild horses (*Equus caballus*) are all possible causes (Singer and Schoenecker 2004). No matter the cause of this rapid population decline, continued monitoring of population size, lamb recruitment rates, mortality rates, rainfall patterns, forage availability, and disease prevalence are important for management of this population into the future.

Measures

- Population size
- Lamb recruitment
- Mortality
- Precipitation
- Forage
- Disease

Reference Conditions/Values

<u>Population Size</u>

The reference condition for this measure is a population size of 150 bighorn sheep; this population size can persist for a long period (Kissell, pers. comm., 2011). Recent surveys from Montana Fish, Wildlife, and Parks (MTFWP) provide raw sighting numbers, but do not predict the total population. The MTFWP management goal is to continue observing 70-100 bighorn sheep each survey, with the ultimate goal of maintaining approximately 150 total sheep (MTFWP 2010).

Lamb Recruitment

MTFWP (2010) considers 40 lambs per 100 ewes during winter counts to be a satisfactory proportion to support a stable population. However, at different population levels, the importance of this index can be misleading. For example, in an extremely small, unstable population, it is still possible to achieve the target proportion of 40 lambs per 100 ewes.

Mortality

There is no reference condition for mortality; the literature does not indicate an acceptable amount of deaths per year to maintain a stable population (Kissell, pers. comm., 2011). The acceptable rate of mortality for a population can change with different population sizes.

Precipitation

The reference condition for rainfall is an average annual rate high enough to produce a sufficient amount of forage the following year. A significant amount of forage is one that allows for acceptable rates of reproduction, recruitment, and maintenance of population size. This amount of rainfall is not defined in the literature nor is data available at this time.

Forage

The reference condition for forage is an adequate quantity and quality to sustain a stable population with healthy lamb recruitment rates (40 lambs per 100 ewes according to MTFWP). A good quality forage habitat includes escape terrain and adequate perennial grass cover.

Disease

The reference condition for disease is the absence of lungworm, bronchopneumonia, or bluetongue in the BICA population. Typically, diseases such as bluetongue are present for long periods, but ungulates in the western United States appear to either be extremely affected or not affected at all (Kissell, pers. comm., 2011), suggesting that when a disease is present, it can be catastrophic to the population.

Data and Methods

The main sources of information for this assessment are literature provided by BICA and by Robert Kissell. He and Shawn Stewart (Wildlife Biologist, MTFWP) provided supplementary data, information, and overall guidance through personal communications.

For the rainfall measure, data from the PRISM Climate Group of Oregon State University were queried and used to examine average monthly precipitation totals in a 2.5-minute by 2.5-minute grid (approximately 4-km by 4-km) (PRISM 2010a). The selected location represents the middle of 2010 bighorn sheep survey locations in BICA (N45.017918, W108.262332). The data sets made available through this group have been created using the PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system, which uses point measurements of climate factors, such as precipitation and temperature, to produce digital grid estimates of monthly, annual, or event-based climate patterns (PRISM 2010a). Historical data sets (from 1920-2010) for average monthly precipitation were queried from the interactive PRISM Data Explorer. Data were downloaded into an Excel spreadsheet and were graphed and charted to examine any patterns that may have occurred in precipitation in the region over the past 90 years.

Current Condition and Trend

Population Size

From 1985-88, Coates and Schemnitz (1989) found the bighorn sheep population of BICA to be increasing at an exponential rate of r=0.18. Kissell et al. (1994) found similar growth rates from 1988-1993, with an exponential rate of r=0.172. The population of bighorn sheep in BICA experienced considerable declines from 1995-2000; the estimated population was around 211 in 1993-1994, and dropped to 85-119 by 2000 (Schoenecker et al. 2004, NPS 2010). Despite this period of population decline, Schoenecker et al. (2004) found that the population may have begun to increase from 2000-2002. These findings are supported by an aerial helicopter survey in which the ram:ewe ratio increased each year: 39:100 in 2000, 58:100 in 2001, and 69:100 in 2002 (Schoenecker et al. 2004). Following the Schoenecker et al. (2004) study, there were habitat restoration projects at Hillsboro, Barry's Island, and Mustang Flats within BICA, and bighorn sheep population increased (NPS 2010). Table 10 and Figure 6 summarize bighorn sheep population estimates from 1985-2003 in BICA.

Table 10. Estimated population size (Roelle 2004).

Biological Year	Season or Date	Population Estimate	Source
1985-86	Fall	38-42	Coates and Schemnitz (1989)
1986-87	Fall	48-52	Coates and Schemnitz (1989)
1987-88		No data available	
1988-89		No data available	
1989-90	(Projected)	99	Coates and Schemnitz (1989)
1990-91		No data available	
1991-92		No data available	
1992-93	Winter	211	Kissell (1996)
1993-94	Winter	211	Kissell (1996)
1994-95	Winter	145	Kissell (1996)
1995-96	Winter	125	Kissell (1996)
1996-97		No data available	
1997-98	3/20/1998	95	Idaho Model
1998-99	1/21/1999	94	Idaho Model
	3/31/1999	47	Idaho Model
1999-00	11/16/1999	72	Idaho Model
2000-01	3/7/2001	115	Idaho Model
2001-02	11/12/2001	61	Idaho Model
2002-03	11/18/2002	113	Idaho Model

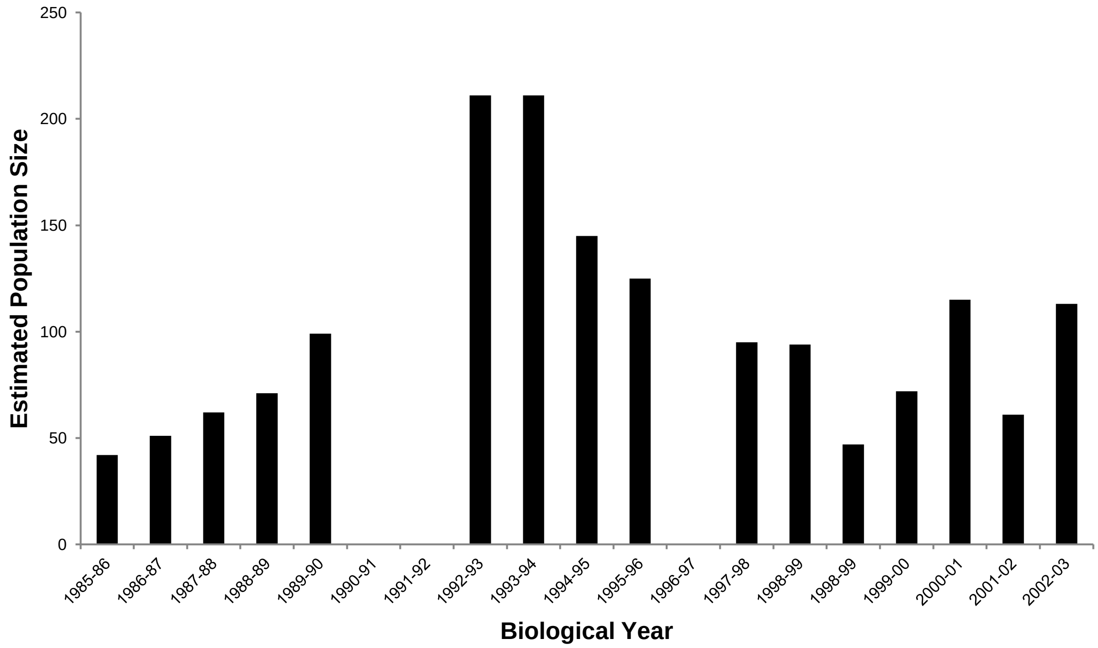

Figure 6. BICA bighorn sheep estimated population sizem 1985-2003 (Roelle 2004).

Shawn Stewart (pers. comm., 2011) at MTFWP found recent population trends to be similar to that of the late 1990s with no signs of large population declines. Stewart has not made population estimates, but has conducted aerial surveys from 1997-2011 (Appendix A); these survey numbers only display the number of sheep seen and not the estimated total population in BICA. In addition, survey numbers vary extremely depending on weather conditions; both 2010 and 2011 had extremely low survey numbers, largely due to the low amount of snow in 2010 and the large amount of snow in 2011. These changes affect the movement patterns of bighorn sheep and can make them hard to observe. Stewart (pers. comm., 2011) predicts that there are currently 100-150 bighorn sheep in BICA. However, there is plenty of uncertainty regarding the total population size and Stewart's prediction may be high (C. Bromley, pers. comm., 2012).

Lamb Recruitment

Lamb recruitment rates are a product of lamb survival and lamb production (Wehausen et al. 1987) and are important in monitoring the population trends of a herd. Potential factors that influence lamb survival rates include herd population density, precipitation, temperature, and disease (Wehausen et al. 1987). Both Wehausen et al. (1987) and Douglas (2001) found a correlation between lamb survival, precipitation, and temperature. Specifically, Douglas (2001, p. 302) found

> the amount and timing of precipitation affects forage nutrients, which in turn affects the ewe's body condition and potential for reproduction. The ewe's nutrition affects her ability to conceive, produce a healthy lamb, and produce enough milk to nurse it to weaning.

Similarly, Wehausen et al. (1987, p. 91) found a “strong relationship between fall and winter precipitation variables and lamb recruitment the following summer or fall,” likely because the amount and timing of precipitation in the fall or winter months relate to the amount and quality of forage available in the following spring and summer. Neither the study by Wehausen et al. (1987) nor by Douglas (2001) took place in BICA, but both studies were conducted in arid climates and their general findings of relationships between precipitation and lamb recruitment are relevant to the BICA herd (Kissell, pers. comm., 2011).

During the considerable decrease in population in 1995-96, there was a very low lamb:ewe ratio (Schoenecker et al. 2004). In the early 2000s, Schoenecker et al. (2004) found the average pregnancy rate for ewes to be 77% ± 4% over four years and average lambing rate to be 68% ± 5% over three years. Roelle (2004) had similar results, with an average pregnancy rate of 73% and an average lambing rate of 72% (Table 11). In 2001 and 2002, 21% (2001) and 44% (2002) of lambs survived to be greater than or equal to one-year-old (Schoenecker et al. 2004). The remaining 79% and 56% of lambs lived for an average of 108±22 days (Schoenecker et al. 2004). Schoenecker et al. (2004) attribute the closure of Bighorn Lake from recreational activities (due to drought conditions) to the dramatic increase in lamb survival rates in 2002; closure of the lake and the associated drawdown of water may have provided a greater amount of habitat, allowing sheep to occupy more areas in the canyon. Data after 2002 are not available, but Robert Kissell (pers. comm., 2011) will track yearlings in the summer of 2011. Table 11 displays 2000-2002 pregnancy and lambing rates from Roelle (2004), and Table 12 displays lambs per 100 ewes from several different reports and surveys. It appears that lambs per 100 ewes ratios since 2002 are generally at or above the suggested 40:100 ratio of MTFWP (2010).

Table 11. Pregnancy and lambing rates of ewes by habitat group (on versus off the wild horse range) and year. Dots in the group column represent animals that utilize habitat both on and off the horse range (Roelle 2004).

Year	Group	Number Pregnant	N	Proportion Pregnant	Number Lambing	N	Proportion Lambing
2000	.	1	1	1	1	1	1
2000	Off	2	5	0.4	3	6	0.5
2000	On	4	4	1	3	4	0.75
2001	.	1	1	1	1	2	0.5
2001	Off	3	5	0.6	6	7	0.86
2001	On	6	10	0.6	7	11	0.64
2002	.	1	1	1	1	1	1
2002	Off	4	5	0.8	5	7	0.71
2002	On	11	13	0.85	11	14	0.79
2000	All	7	10	0.7	7	11	0.64
2001	All	10	16	0.63	14	20	0.7
2002	All	16	19	0.84	17	22	0.77
All	.	3	3	1	3	4	0.75
All	Off	9	15	0.6	14	20	0.7
All	On	21	27	0.78	21	29	0.72
All	All	33	45	0.73	38	53	0.72

Table 12. Available age ratio data (lambs/100 ewes). Data from Kissell et al. 1996, Idaho Sightability Model, Coates and Schemnitz 1989 (Roelle 2004), Kissell 2011, and MTFWP.

Biological Year	Season or Date	Age Ratio (lambs/100 ewes)	Source
1986-87	Summer	60	Coates and Schemnitz (1989)
1987-88	Summer	51.9	Coates and Schemnitz (1989)
1988-89	Summer	54.8	Coates and Schemnitz (1989)
1989-90		No data available	
1990-91		No data available	
1991-92		No data available	
1992-93	Winter	37.1	Kissell et al. (1996)
	Spring	24.8	Kissell et al. (1996)
1993-94	Summer	50	Kissell et al. (1996)
	Fall	55.6	Kissell et al. (1996)
	Winter	55	Kissell et al. (1996)
	Spring	50.5	Kissell et al. (1996)
1994-95	Summer	36.1	Kissell et al. (1996)
	Winter	6.8	Kissell et al. (1996)
1995-96	Summer	56.4	Kissell et al. (1996)
	Winter	21.3	Kissell et al. (1996)
1996-97		No data available	
1997-98	3/20/1998	24.2	Idaho Sightability Model
1998-99	1/21/1999	36.7	Idaho Sightability Model
	3/31/1999	15	Idaho Sightability Model
1999-00	11/16/1999	11.6	Idaho Sightability Model
2000-01	3/7/2001	16.6	Idaho Sightability Model
2001-02	11/12/2001	14	Idaho Sightability Model
2002-03	11/18/2002	52.6	Idaho Sightability Model
2003		18	MTFWP
2004		29	MTFWP
2005		66	MTFWP
2006		40	MTFWP
2007		No data available	
2008		47	MTFWP
2009		67	MTFWP
2010	December	41.2	Kissell (2011)
2011		50	MTFWP

Mortality

Sixty-one sheep deaths were documented from 1997-2003 in Hells Canyon (Cassirer and Sinclair 2007). Of the documented deaths, 49 had causes identified for them: 21 (43%) from disease, 13 (27%) from cougar (*Puma concolor*) predation, 11 (22%) from falls or injuries, and 4 (8%) from human-caused death. However, an ongoing study within BICA indicates that cougar predation may play a more important role in sheep mortality than indicated by Cassirer and Sinclair (2007)

(Bromley, pers. comm., 2011). In 90% of bighorn sheep that died from disease, there was "moderate to severe, acute to chronic, fibrinosuppurative, necrotizing bronchopneumonia, occasionally accompanied by pleuritis or tracheitis" (Cassirer and Sinclair 2007, p. 1082). Cassirer and Sinclair (2007) found adult mortality to occur from September to May. In addition, the cause of death appeared to be seasonal: between October and January, disease accounted for 70% of deaths; and between February and May, predation accounted for 50% of deaths (Cassirer and Sinclair 2007). Average age of death was less than eight years 59% of the time for females, and 87% of the time for males (Cassirer and Sinclair 2007).

Bronchopneumonia, a disease caused by pasteurellosis (*Mannheimia haemolytica*), has the potential to kill bighorn sheep at any age (Schoenecker et al. 2004). Pneumonic pasteurellosis is contagious and has caused massive declines in bighorn sheep populations (Onderka and Wishart 1984, as cited in Schoenecker et al. 2004). Typically, pneumonic pasteurellosis causes nasal discharge and coughing, and eventually leads to an initial period of mass deaths and low lamb survival rates (Foreyt 1990). After this initial period of mass deaths, adults become immune to the disease, but lambs remain susceptible (Schoenecker et al. 2004). In BICA, population decrease could be partially caused by disease (Schoenecker et al. 2004). Schoenecker et al. (2004) found high levels of pasteurellosis antibodies in BICA sheep in 2001, but the presence of antibodies does not guarantee the disease caused the major population decline. In addition to disease, an exceedance of their carrying capacity, competition with wild horses, or predation are also possible causes to the decrease in population. There are also four hunting tags issued annually, all of which are filled nearly every year (MTFWP 2010). R. Kissell (pers. comm., 2011) suggested that the decrease in bighorn sheep population in 1995 could be a result of the large decline in mule deer (*Odocoileus hemionus*) in the early 1990s due to bluetongue disease; this decline could have increased predation on bighorns by cougars due to the absence of mule deer. Table 13 summarizes adult survival rates for sheep in BICA for a three-year period.

Table 13. Survival of adult sheep (Roelle 2004).

Year	Sex	Number Alive at Start	Number Alive at End	Annual Survival Rate	Standard Error
2001	F	13	11	0.85	0.1
2001	M	7	7	1	0
2002	F	23	20	0.87	0.07
2002	M	15	13	0.87	0.088
2003	F	20	18	0.9	0.067
2003	M	13	13	1	0
2001	All	20	18	0.9	0.067
2002	All	38	33	0.87	0.055
2003	All	33	31	0.94	0.042
All	F	56	49	0.88	0.044
All	M	35	33	0.94	0.039
All	All	91	82	0.9	0.031

<u>Rainfall</u>

Picton (1984) found statistically significant correlations between climate and survival of offspring for bighorn sheep; these findings were based on the Lamb climate index (Lamb 1963).

Picton's results were based on the theory that populations at or near their carrying capacity are most strongly impacted by climatic changes. Picton (1984) found, "nine of the 12 months in the November-October period contributed information to the correlation between precipitation and sheep reproduction" (p. 867). Similarly, Rubin et al. (2000) found that "months of peak parturition followed annual winter rains and, therefore, were likely to coincide with periods of high plant productivity" (p. 769). McKinney et al. (2001) also found trends that supported Wehausen et al. (1987), in that rainfall during the fall or winter influenced lamb recruitment the following year.

Monthly rainfall data in BICA from 1920-2010 are displayed in Appendix B. Table 14 displays monthly mean precipitation and total precipitation for years 1992-1999, which were the years that saw a population decline for bighorn sheep. Literature (Wehausen et al. 1987, Douglas 2001) indicates that winter months are the most important in determining the following spring's forage productivity, and Kissell (pers. comm., 2011) indicated that there is generally a one or two year lag for the effects of high or low rainfall to become apparent in a population. According to the population estimates as described in Roelle (2004) (Table 10), the bighorn population began to drop significantly in 1995, suggesting that if precipitation played a role in the decrease in population, 1992-1994 precipitation would have been the critical years to analyze. Figure 7 displays the monthly precipitation totals from 1992-1994 along with the mean precipitation from 1920-2010. These simple comparisons show the November and December precipitation totals from 1993 and 1994 to be lower than the mean. However, these discrepancies do not necessarily indicate a causal relationship between the lower precipitation totals and the considerable decrease in population in the 1995-1996.

Table 14. Monthly precipitation totals from 1992-1999 and mean precipitation (from 1920-2010). Highlighted months depict the critical winter months (PRISM 2010b).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1992	0.01	0	0.27	0.59	1.32	3.2	1.03	0.52	0.12	0.36	0.3	0.43	8.15
1993	0.28	0.09	0.06	0.96	1.09	1.01	2.87	0.55	0.04	1.19	0.12	0.05	8.31
1994	0.1	0.19	0.47	0.55	0.55	0.16	0.43	0.11	0.92	1.41	0.14	0.01	5.04
1995	0.07	0.01	1.04	0.93	1.35	0.75	1.43	0.16	1.2	0.25	0.14	0.11	7.44
1996	0.44	0.41	0.6	0.49	1.88	0.52	0.02	0.27	1.09	0.08	0.29	0.42	6.51
1997	0.29	0.19	0.1	0.39	0.77	2.79	2.09	0.62	0.31	1.26	0.09	0.11	9.01
1998	0.68	0.14	0.35	0.29	0.41	1.74	0.92	1.2	0.7	0.99	0.29	0.12	7.83
1999	0.13	0.12	0.05	1.12	1.04	0.65	0.18	0.2	0.46	0.24	0.08	0.42	4.69
Mean	0.25	0.19	0.34	0.67	1.25	1.34	0.71	0.54	0.69	0.56	0.26	0.22	7.03

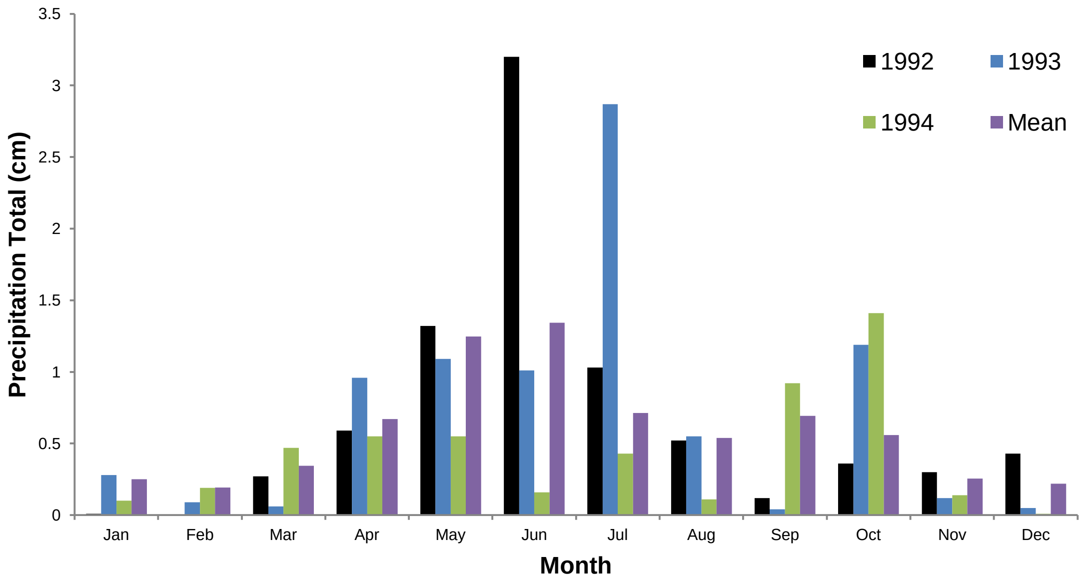

Figure 7. 1992-1994 monthly precipitation totals compared to mean precipitation (PRISM 2010b).

Forage

Coates and Schemnitz (1994) found that grasses dominated the bighorn sheep diet in BICA. Coates and Schemnitz (1994) also found differences in bighorn sheep eating patterns, depending on the presence of wild horses; when wild horses were present, bighorns were located in Utah juniper (*Juniperus osteosperma*) woodlands 83% of the time (Coates and Schemnitz 1994). When there were only bighorn sheep present (no wild horses), bighorns were found in juniper/mountain mahogany (*Cercocarpus* spp.) woodlands 85% of the time. However, it is not clear where Coates and Schemnitz (1994) study area occurred in BICA.

Singer and Schoenecker (2004), Gerhardt (2004), and Peterson (1999) analyzed the effects of grazing on forage biomass by using exclosures. Singer and Schoenecker (2004) found five variables to be significantly different inside and outside exclosures: total plant cover, grass cover, litter cover, bare ground, and relative cover of grasses. Both Gerhardt (2004) and Singer and Schoenecker (2004) found total biomass and grass biomass to be higher inside exclosures and forb biomass to be higher outside exclosures. These findings indicate that the grazing effects from both bighorn sheep and wild horses significantly influences grass biomass. Singer and Schoenecker (2004) also found that there was much more bare ground and lower species richness in grazed areas. However, Singer and Schoenecker (2004) found that grazing is not affecting the cushion plant communities.

R. Kissell indicated that Bureau of Land Management (BLM), U.S. Forest Service (USFS), and other independent researchers have suggested an overall degradation of the range; specifically, there is an apparent change in the mountain mahogany woodlands, which bighorn sheep prefer. However, bighorn sheep are opportunistic feeders, and an area with high quality forage will not always be selected over an area with lesser forage quality (Kissell 2011); rather, other important factors, such as the possibility of predation and proximity to escape terrain (Gudorf et al. 1996), primarily determine if bighorn sheep will utilize a given area or not. Bighorns prefer mountain mahogany woodlands because they provide food, but also because they allow for good visibility. Bighorn sheep prefer areas with high visibility because they are less susceptible to predation in those areas. Juniper encroachment and growth is reducing visibility, which makes bighorns more susceptible to predation. Because of the encroachment of juniper into mountain mahogany woodlands, park staff members are working to reduce juniper from mountain mahogany areas through prescribed burns (Photo 4).

Photo 4. BICA staff torching juniper (NPS photo).

Threats and Stressor Factors

BICA identified predation (cougar) and forage availability as the primary stressors for bighorn sheep in the park. Singer and Schoenecker (2004) found bighorn sheep predation to occur around BICA; in the Schoenecker et al. (2004) three-year study, cougars only accounted for four of the 13 deaths on 43 radio-collared bighorns. Singer and Schoenecker (2004) suggested this number was relatively low, but also noted that there were no baseline data to compare their findings. Festa-Bianchet et al. (2006) found that in general, cougars had to learn how to hunt bighorn sheep in order to be successful, and if they did learn, bighorn sheep quickly became a primary food source for cougars. However, cougars that did not learn to hunt bighorns and utilize them as a primary food source did not generally attempt to hunt them (Festa-Bianchet et al. 2006). Ongoing research in the park indicates that one female cougar is responsible for a majority of the recent predation on bighorn sheep (Bromley, pers. comm., 2012).

Forage availability is a threat to bighorn sheep, largely because of minimal rainfall in the fall and winter months; most of the rainfall occurs during spring at BICA, when it is warm enough for plant growth. Wehausen et al. (1987) and Douglas (2001) both found relationships between lower rainfall amounts and the health of the herd. This is largely due to the amount and quality of forage available for ewes, which in turn affects their ability to successfully produce a healthy lamb that can reach one year of age. In addition to precipitation, juniper expansion is a threat to forage availability. Juniper outcompeting mountain mahogany could reduce the quality of available forage in the future. Chapter 4.4 discusses forage in greater detail.

Data Needs/Gaps

An up-to-date population estimate would be useful to understand the population dynamics of bighorn sheep in BICA. MTFWP has conducted aerial surveys, but they have not established population estimates from these surveys.

Continued monitoring of lambs reaching one year of age is necessary to better understand the current, and future, bighorn sheep population.

An advanced analysis looking at correlations between monthly precipitation totals, mean precipitation, and population trends would be beneficial to further understand the relationship and significance precipitation had in the population decline in the 1990s.

An updated forage use versus food availability study would be beneficial, given the changes in the mountain mahogany woodlands in BICA (Kissell, pers. comm., 2011).

Overall Condition

Population Size

The project team defined the *Significance Level* for population as a 3. Kissell (pers. comm., 2011) indicated that approximately 150 sheep would be a healthy number that could sustain a population for a long period. Currently, Stewart (pers. comm., 2011) estimates there are approximately 100-150 bighorns in BICA, indicating low concern. However, there is plenty of uncertainty regarding the size of the sheep population. Therefore, the *Condition Level* for this measure is 2, indicating moderate concern.

Lamb Recruitment

The project team defined the *Significance Level* for lamb recruitment as a 3. MTFWP (2010) stated that a healthy bighorn population in Montana would have a lamb to ewe ratio of 40:100. Since 2005, the lamb to ewe ratio has been at or above 40:100 each year, indicating that lamb recruitment is currently of no concern (*Condition Level* of 0). Because of this, SMUMN GSS assigned lamb recruitment a *Condition Level* of 0.

Mortality

The project team defined the *Significance Level* for mortality as a 3. R. Kissell (pers. comm., 2011) indicated that there have not been studies to determine the annual amount of mortality the population can withstand. Roelle (2004) studied mortality rates for 2001, 2002, and 2003, and found mortality to be at or below 15% of the population for each year. However, with no baseline data to compare these trends, the current condition of mortality rates is undetermined and no *Condition Level* can be assigned.

Rainfall

The project team defined the *Significance Level* for rainfall as a 2. The reference condition for rainfall was a sufficient amount of rainfall to produce enough forage the following year. While the precipitation totals during recent years appear to be in line with monthly means from the last 90 years, the current condition and trend is undeterminable without more advanced analyses of precipitation data and no *Condition Level* was assigned.

Forage
The project team defined the *Significance Level* for forage as a 2. Bighorn sheep favor mountain mahogany woodlands as a food source and as a habitat with good visibility. Juniper woodlands are encroaching on these mountain mahogany areas, and subsequently, the park has worked extensively to burn junipers. Because of these efforts, and because bighorn sheep are largely opportunistic feeders and select habitat on more than just nutritional value, SMUMN GSS defined the *Condition Level* of forage as a 1.

Disease
The project team defined the *Significance Level* for disease as a 1. Kissell (pers. comm., 2011) stated that years with low precipitation and forage productivity make bighorns more susceptible to disease. When disease is present, it appears to cause extensive damage, but in most years, disease does not play a role (Kissell, pers. comm., 2011). Because there currently appears to be few issues with disease, SMUMN GSS defined the *Condition Level* for disease as a 0.

Weighted Condition Score
The *Weighted Condition Score* for bighorn sheep was 0.296, meaning their condition is currently of low concern. Neither the mortality nor rainfall measures were scored due to lack of baseline quantitative data. However, four of six measures were scored. If baseline data became available and the mortality and rainfall measures were able to be scored, it is possible the overall weighted condition score could change. The bighorn sheep population in BICA varies considerably based on past observations and continued monitoring is vital to ensure appropriate management actions and long-term survival in the Pryor Mountains area.

Bighorn Sheep

Measures	SL	CL
Population size	3	2
Lamb recruitment	3	0
Mortality	3	n/a
Rainfall	2	n/a
Forage	2	1
Disease	1	0

WCS = 0.296

Sources of Expertise
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4.6 Wild Horses

Description

The Pryor Mountain Wild Horse Range (PMWHR) encompasses 153 square kilometers (38,000 acres), and is located approximately 80 kilometers (50 miles) south of Billings, Montana, and 16 kilometers (10 miles) north of Lovell, Wyoming (BLM 2009). Created in 1968 by the U.S. Department of the Interior, the land is currently managed by the BLM, USFS, and the NPS (Singer and Schoenecker 2000, Ricketts et al. 2004). In 1969, NPS lands were added to the PMWHR including a portion of BICA (Plate 9) (BLM 2008b). The NPS now manages and maintains approximately one quarter of the PMWHR; Montana Department of Fish, Wildlife and Parks and the Wyoming Game and Fish Department oversee hunting and fishing, and BLM manages the wild horse population (Singer and Schoenecker 2000, Ricketts et al. 2004, BLM 2009). This differing ownership creates a range of management philosophies in the area (Singer and Schoenecker 2000, Ricketts et al. 2004). There is also a strong social connection between the horses and the general public; close followers of the wild horses intensely scrutinize all management actions or proposals (Bromley, pers. comm., 2012).

Photo 5. Pryor Mountain feral horse (NPS photo).

Feral horses (Photo 5) have presumably been present in the Pryor Mountains for over two centuries and are thought to be descendants of Spanish horses (Singer and Schoenecker 2000). The horses are rather small, even by wild horse standards, and average about 13 hands tall (52 inches) with larger individuals reaching nearly 14 hands high (56 inches). These horses are rather docile and extremely tolerant to the presence of humans allowing for them to be easily viewed, photographed, and filmed (Bybee, pers. comm., 2012). They also have a passionate following by a segment of the public and are one of the primary reasons people visit BICA and the PMWHR.

The BLM closely monitors the horse population and excess horses are often removed to keep numbers under the maximum carrying capacity (Glover 2001). These horses are genetically unique and are protected as “living symbols of the historic and pioneer spirit of the West” under the 1971 Wild and Free-Roaming Horses and Burros Act (BLM 2006, p. 1).

Measures

- Population size (Appropriate management level)
- Water availability
- Forage availability
- Cover and space availability
- Herd health (Genetic diversity, reproductive success)

Reference Conditions/Values

Population Size (Appropriate Management Level)
The reference condition for population size is the "Appropriate Management Level" (AML) defined by the BLM (2009). In 1992, the maximum carrying capacity of the PMWHR was set at 95 adult horses (BLM 2008a). Following an environmental assessment in 2009, the AML changed from 95 ± 9.5 individuals to 90 to 120 individuals in the herd (BLM 2009). The PMWHR area overseen by the NPS has potential habitat for about 12 horses based on the conclusions of Ricketts et al. (2004) of 146 animal unit months (AUM). However, since the horses are rather transitory, individuals are not necessarily found in one location year-round, frequently leaving and returning to BICA. While the BLM is responsible for managing horses, the NPS manages their land and resources and has authority over management actions within the NPS portion of the PMWHR (Bybee, pers. comm., 2012).

Water Availability
The reference condition for water is an adequate year-round supply in both quantity and quality able to sustain wild free-roaming horse and numbers within the AML (BLM 2010). If baseline access and availability information does not exist, then an inventory of public land water should be conducted (BLM 2010). According to the BLM (2010) manual, if water on privately-owned land is necessary for sustainability, agreements should be made for the rights to that resource, otherwise the AML should be adjusted or the herd management area (HMA) removed. Generally, water sources must be available to horses during the dry season and open winters. Water developments and modifications, such as guzzlers, must provide water access to wild horses. In addition, changes in distribution of water sources across the landscape causes shifts in grazing pressure locations (Bromley, pers. comm., 2012).

Forage Availability
The BLM (2010, p. 12) states, "an authorized officer should determine whether vegetation provides sustainable forage (and cover) for the animals." Generally, there must be sustainable forage to provide adequate nutrition and survival for wild horses that utilize the PMWHR area. The similarity index, a rating that compares the present weighted species composition to that of historic climax plant communities (HCPC), is used to evaluate range and forage condition (Ricketts et al. 2004). This value helps to determine the departure from HCPC, with a higher rating indicating greater similarity between current and historic reference plant communities. As an evaluator of overall rangeland health, a site index was used by Ricketts et al. (2004) to determine average rangeland health ratings for each of the PMWHR management units. Scores of 4-5 are considered healthy, 2.6-3.9 are considered at risk, and a score lower than 2.5 is considered unhealthy (BLM 2008b). Essentially, each HMA is managed so that a thriving natural ecological balance is sustained with adequate vegetation (BLM 2010).

Cover and Space Availability
The reference condition for cover and space is adequate terrain and vegetation to roam and provide shelter from weather (BLM 2010). According to the BLM (2010), horses must be allowed to move between water and forage freely, with only necessary manmade barriers present. Terrain and vegetation should provide thermal protection, escape, and shade while allowing free-roaming behavior and movement between grazing areas or water sources within the PMWHR. There is currently not a defined quantifiable measure in place for available cover

and space (Bybee, pers. comm., 2012). As current available literature does not allow for direct quantifiable comparison, common trends in literature determined overall condition.

<u>Herd Health (Genetic Diversity, Reproductive Success)</u>
The reference condition for herd reproductive success is the measure of heterozygosity. Recruitment rates should also keep pace with mortality (Bybee, pers. comm., 2012). The long term recruitment rate goal is 17.5%; however, even with a lower recruitment rate, herd health may not be severely impacted as long as heterozygosity remains high. For conservation of genetic diversity, the BLM goal is to avoid inbreeding depression by assessing genetic diversity every 6 to 10 years. If genetic diversity, observed heterozygosity as the most important measure, is less than desired after testing several measures (e.g., expected heterozygosity and effective number of alleles), herd reassessment must occur more frequently (every 3 to 5 years) (BLM 2010). The mean value for feral horse populations is 0.66 for hair samples and 0.31 for blood samples, with one standard deviation below the mean indicating that a herd is at critical risk for decreased genetic diversity (BLM 2010). According to the BLM (2010), structural improvement projects, such as fences and water developments, must protect genetic interchange between herds.

Data and Methods
The BLM maintains much of the population data for the PMWHR portion of BICA. The BLM conducted several environmental assessments in the PMWHR including management of wild horses, plant communities, and resources within the BICA segment (BLM 2008b, 2009). BLM (2010) lists and describes several quantifiable standards, such as population limits, by which the PMWHR rangelands are managed. Trend determination using Daubenmire plots was established through a comparison of rooted frequency between the two study years (1996 and 2007) (BLM 2008b).

Ricketts et al. (2004) performed a comprehensive survey and assessment of the PMWHR in which the authors describe range findings. Ricketts et al. (2004) – also reported in BLM (2008b) – used a similarity index to determine succession of certain sites by measuring present vegetative composition and comparing it to that of the historic climax plant communities (HCPC). This index is estimated as a percentage of the HCPC, ranging from 1% to 100% with a climax plant community without major disturbances represented as 100% (Ricketts et al. 2004, BLM 2008b). Ricketts et al. (2004) evaluated overall rangeland health using a site index, which employed a scale from one to five, one indicating a total departure from HCPC and five indicating similar HCPC conditions. The Ricketts et al. (2004) study also determined forage condition by sampling different ecological sites throughout the PMWHR and comparing the results to HCPC, plant species composition, and erosion rates (Ricketts et al. 2004, Bybee, pers. comm., 2012).

Cothran (2010) performed multiple years of genetic analysis for the Pryor Mountain horse population (1994, 1997, 2001, 2009), testing for multiple measures of genetic variability. In addition, Roelle et al. (2010) examined foaling rates of the Pryor Mountain horse population from 1993-2007. They compared results to other studies of the Pryor Mountain population and those of other wild horse herds. Both sources provided information on overall herd health – genetic diversity and reproductive success.

Current Condition and Trend

<u>Population Size (Appropriate Management Level)</u>
The BLM (2009) provides population data for the Pryor Mountain horse population from 1971-2009. Over that time, the population was below the current AML on only one occasion (1978, 87 individuals). For most years since 1971, the population exceeded the upper level of the current AML (120 individuals) (Figure 8). Over the last 10 years of data (2000-2009), the mean yearly population size (excluding new foals) was 165 individuals, ranging from 142 to 195. This is a cause for concern regarding range condition.

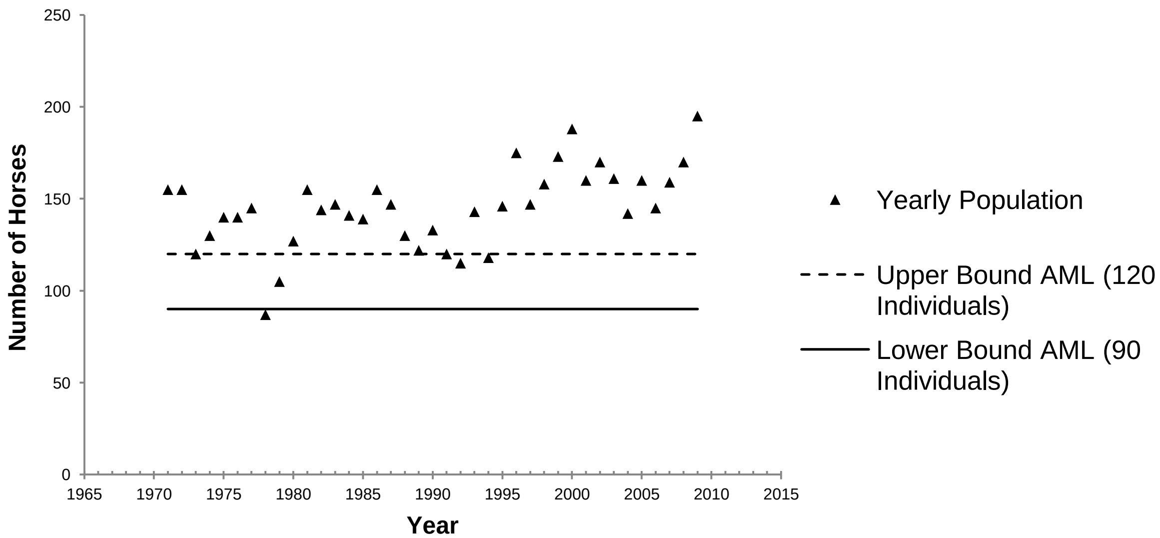

Figure 8. Pryor Mountain wild horse population, 1971-2009 (BLM 2009).

As of late 2011, the PMWHR contained 156 adult horses and 18 foals. The BLM has proposed the gathering and removal of excess PMWHR wild horses during the 2012 calendar year, which would reduce the population to a more manageable level (BLM 2012). The PMWHR area overseen by the NPS has habitat potential for 20-25 horses (Bybee, pers. comm., 2012).

<u>Water Availability</u>
Within the PMWHR, water is typically available to horses and plentiful for most of the year. However, water is still considered somewhat limited, as the PMWHR contains only five perennial water sources (BLM 2008b). In addition, Ricketts et al. (2004) found that some water sources are only available infrequently or for short periods. According to Bybee (pers. comm., 2012), water is usually plentiful in the summer months at the Crooked Creek Bay and Layout Creek locations in the BICA portion of the PMWHR. Horses usually consume snow in the winter months. However, lack of snow or frozen water sources occasionally result in stressed conditions, forcing horses to seek out other water sources within the PMWHR (Bybee, pers. comm., 2012).

Ricketts et al. (2004) suggested controlling water sources to allow growing-season rest for overgrazed plant communities. The BLM proposed the use of "guzzlers," (Photo 6) devices used to collect rainwater and provide sources of drinking water to horses, on rangelands. In 2010, the BLM installed 10 guzzlers within PMWHR (Mullen 2011). These guzzlers were placed in areas of undergrazing, encouraging horse utilization of specific habitat and better distributing horses in the range (BLM 2009, Mullen 2011). The NPS is currently developing water sources, both independently and in collaboration with the BLM, on BICA rangelands within the PMWHR (Bybee, pers. comm., 2012).

Photo 6. PMWHR "guzzler" installed in 2010 (BLM 2009).

Forage Availability

Since the mid-1930s, efforts to control feral horses due to overgrazing and problems with soil erosion occurred. According to Ricketts et al. (2004), an inherent conflict exists between the preservation of wild and free-roaming horses and range management without land or productivity impairment.

Ricketts et al. (2004) described proper forage utilization as <50% use of a preferred forage plant (Table 15) (Crider 1955, as cited in Ricketts et al. 2004), although Holechek et al. (1999), suggested that 35-45% use of forage was more appropriate for moderate grazing in semi-arid grasslands and rangelands.

Table 15. Preferred forage plant species by wild horses in the PMWHR. Table modified from Ricketts et al. (2004).

Common Name	Scientific Name
alkali bluegrass (Sandberg bluegrass)	*Poa secunda* (*Poa juncifolia*)
alpine bentgrass	*Agrostis humilis*
alpine foxtail	*Alopecurus alpinus*
alpine timothy	*Phleum alpinum*
bearded wheatgrass	*Elymus subsecundus*
bentgrass sp.	*Agrostis* sp.
big bluegrass	*Poa secunda* (*Poa ampla*)
blazing star sp.	*Liatris* sp.
bluebunch wheatgrass	*Pseudoroegneria spicata*
bottlebrush squirreltail	*Elymus elymoides*
browse milkvetch	*Astragalus cibarius*
Columbia needlegrass	*Achnatherum nelsonii (Stipa columbiana)*
Cusick's bluegrass	*Poa cusickii*
fourwing saltbush	*Atriplex canescens*
Idaho fescue	*Festuca idahoensis*
Indian ricegrass	*Achnatherum hymenoides*
kingspike fescue	*Leucopoa kingii*
Letterman's needlegrass	*Achnatherum lettermanii*
little ricegrass	*Piptatherum exiguum*
Montana wheatgrass	*Elymus albicans*
needleandthread	*Hesperostipa comata*
Nuttall's saltbush	*Atriplex nuttallii*
plains reedgrass	*Calamagrostis montanensis*
prairie junegrass	*Koeleria macrantha*
purple prairie clover	*Dalea lasiathera*
purple reedgrass	*Calamagrostis purpurascens*
rough bluegrass	*Poa trivialis*
sheep fescue	*Festuca ovina*
slender wheatgrass	*Elymus trachycaulus*
thickspike wheatgrass	*Elymus macrourus*
threadleaf sedge	*Carex filifolia*
western wheatgrass	*Pascopyrum smithii*
Wheeler bluegrass	*Poa nervosa*
white prairie clover	*Dalea candida*
winterfat	*Krascheninnikovia lanata*

Demand, dietary overlap, availability, and grazability are forage aspects used to assess range condition. Kissel et al. (1996) and Ricketts et al. (2004) both determined that, except for parts of the summer season, there is little dietary overlap between feral horses and mule deer/bighorn sheep. Therefore, there is generally minimal competition between these animals for forage resources. However, when widespread, poor range conditions occur, many species experience stress (Bromley, pers. comm. 2012). Ricketts et al. (2004) found that, based on several assumptions, 1,189 AUM of forage is required to sustain 161 horses every 12 months. Ricketts et al. (2004) used a similarity index, a rating that compares the present weighted species composition to that of historic climax plant communities (HCPC); it is a repeatable and quantitative measurement system that can be used as a quantifiable indicator of native plant community health. The site index, or departure from HCPC, for the BICA portion of the PMWHR, was 2.25 out of 5 (Ricketts et al. 2004). This evaluation is considered a moderate to extreme departure for a rangeland health rating (Ricketts et al. 2004, Bybee, pers. comm., 2012).

The similarity index, expressed as a percentage, takes into account the amount and type of vegetation present relative to the HCPC (with current vegetation diversity and productivity equal to the HCPC described as 100%) (NRCS 1997). This index evaluates both species diversity and productivity as a single quantitative measure showing ecological status of the local plant community (Ricketts et al. 2004). Within the National Park PMWHR inventory unit, a similarity index of 44% was determined as of 2004, showing a significant disparity between current plant communities and HCPC (Ricketts et al. 2004). Ricketts et al. (2004) described a downward trend in similarity index values, which is in conflict with current range management objectives.

The use of Daubenmire plots, a canopy-coverage method of sampling and vegetation analysis that takes into account canopy cover and rooted frequency of plant species, by the BLM allowed for the detection of change in vegetation and overall trend. Based on the results of this analysis, a steady to slightly downward trend was seen in the status of native plant communities between 1996 and 2007 throughout the PMWHR, with a downward trend indicated for the Mustang Flat plot located within the BICA portion of the PMWHR (Table 16, BLM 2008b). Canopy cover was not used in determination of trend in this study because of changes in cover and variable precipitation regimes (BLM 2008b).

Table 16. Daubenmire plots analyzed by BLM (2008b) showing change and overall trend in native plant communities from 1996 to 2007, based on frequency of rooted vegetation within plots. The Mustang Flat plot is located within the NPS portion of the PMWHR. Table modified from BLM (2008b).

Trend Plot	Years Read	Change Detected	Indicated Trend
Mustang Flat	1996, 2007	50% decrease in bluebunch wheatgrass, 50% increase in needle and thread grass, increase in three-awn, increase in snakeweed	Downward
Burnt Timber F.S. Boundary	1996, 2007	Bluebunch wheatgrass increased, mainly seedlings; Bluegrass and June grass have decreased, almost gone from the plot; Black sagebrush has increased.	Steady to slightly downward
Burnt Timber Catchment	1996, 2007	400% increase in bluebunch wheatgrass, Indian rice grass now present with a 700% increase, black sage brush has decreased	Upward
Lone Pine Basin	2007	No change detected	One point in time
Turkey Flat	1996, 2007	Bluebunch wheatgrass and June grass are no longer present, needle and thread grass 50% decrease, threeawn now present on site at a 900% increase	Downward
Sykes Catchment	1996, 2007	50% increase in bluebunch wheatgrass, 50% increase in Junegrass, slight increase in winterfat	Upward

Cover and Space Availability

Rangelands must provide adequate terrain for wildlife to roam (BLM 2010). Since the amount of area available to horses is limited by Secretarial Order, the Wild Free-Roaming Horse and Burro Act, and the closure of the Sorenson area, open space remains a very important issue (BLM 2008b, Bybee, pers. comm., 2012). According to Bybee (pers. comm., 2012), cover may not be as important as open roaming space.

The most recent land adjustment occurred in 1990, when the Sorenson Extension was closed because the the special use permit was not renewed, reducing the amount of available land in the PMWHR (BLM 2008b). Occasionally horses are found outside of the PMWHR, generally indicating lack of suitable habitat or inaccessibility of grazing lands or water sources (BLM 2008b). According to the BLM (2008b, p. 43), “wild horses moving into new areas are also an indicator of an over-population beyond the capabilities of the resource to sustain themselves.” The BLM (2008b, p. 44) also notes that dense tree growth has apparently been negatively affecting wild horse habitat as tree density “does not allow for a higher level of wildlife and wild horses to be maintained within the PMWHR.”

Feral horses are currently allowed to move between water and forage areas freely, as well as between management units. Bands of horses usually exhibit a small occupied home range, changing slightly based on seasonal shifts and roaming patterns (BLM 2008b). Land use by horses tends to shift with availability of forage and elevation accessibility (BLM 2008b). J. Bybee (pers. comm., 2012) notes that south and western-facing slopes containing juniper woodlands are very adequate for providing thermal cover in winter months and shade in the summer months, for such a limited number of horses.

Herd Health (Genetic Diversity, Reproductive Success)

Genetic Diversity
Cothran (2010) examined 105 samples from the Pryor Mountain horse population, testing for multiple measures of genetic variability:

- Observed heterozygosity (*Ho*): the actual number of loci heterozygous per individual
- Expected heterozygosity (*He*): the predicted number of heterozygous loci based upon gene frequencies
- Effective number of alleles (*Ae*): measure of marker system diversity
- Total number of variants (*TNV*)
- Mean number of alleles per locus (*MNA*)
- Number of rare alleles (*RA*): number of alleles observed which occur with a frequency of 0.05 or less
- Percent of rare alleles (*%RA*)
- Estimated inbreeding level (*Fis*): 1-*Ho/He*

Variation was examined for 12 equine microsatellite systems (short DNA sequences).

Cothran (2010) also examined the "genetic resemblance" of the Pryor Mountain population in comparison to domestic horse breeds, using Rogers' genetic similarity coefficient. Cothran (2010) utilized the restricted maximum likelihood (RML) procedure to summarize the results. The results from 2001 and 2009 were compared to those from 1994 and 1997 at nine common loci. Allelic diversity and heterozygosity remained consistent for 1994, 1997, and 2001 (Cothran 2010). Results from 2009 for these measures differed from previous samples though; heterzygosity levels were higher and *TNV*, *MNA*, and *%RA* were lower. *Ae* was also higher, "which indicates an evening out of allele frequencies" (Cothran 2010, p. 4). Cothran (2010, p. 4) suggests that "the changes in variation show the effects of the removal of horses that were known to have ancestry outside the Pryor Mountain HMA". Based on Cothran's results, the herd appears to be in genetic equilibrium, showing high levels of genetic diversity, with no evidence of genetic drift or population bottlenecking. Cothran (2010, p. 5) suggests that the current variability levels in the population are high enough that no specific management action is required, but "it is important that the population size of the herd be maintained at the level of a minimum of 120 breeding-aged animals".

Reproductive Success
Roelle et al. (2010) examined the foaling rates of the Pryor Mountain horse population from 1993-2007. Pooled yearly data over the duration of the study, mares ≥2 years of age produced 0.501 foals/mare (range=0.254-0.705), mares ≥3 years of age produced 0.576 foals/mare (range=0.300-0.795), and mares ≥4 years of age produced 0.597 foals/mare (range=0.311-0.795).

Roelle et al. (2010) found that foaling rates for the Pryor Mountain horse population were intermediate. According to Roelle et al. (2010), other researchers suggested that forage availability could affect mare foaling rates (Green and Green 1977, Nelson 1978, Berger 1986, Siniff et al. 1986, Garrott and Taylor 1990). There are also many other factors hypothesized to affect foaling rates: gathers (round-ups), band stability (social hierarchies), and parturition history of a mare (Roelle et al. 2010). Even though Roelle et al. (2010, p. 22) did not specifically examine the effects of gathers in subsequent years, they noted that, "we had to assume that the majority of mares were affected by the gather in each of the three years that we considered to be gather years."

The fertility control drug porcine zona pellucid (PZP) has been used in some form since 2001 in order to limit fertility; however, prior to 2009 only about 25% of mares received treatment (BLM 2011). Currently, PZP is applied to approximately 70% of PMWHR mares, with a BLM goal of over 80% application (BLM 2011). NPS personnel also apply fertility control to mares within the BICA portion of the PMWHR and on adjacent BLM and Forest Service lands, since horses frequently travel between locations. According to Bybee (pers. comm., 2012), over 700 horses have been removed from the PMWHR since removal efforts began in the early 1970s. The BLM management goal is to balance recruitment with mortality, with a long term recruitment rate of 17.5%. The 2011 recruitment rate was only 11.5%, and is presumably heading in the right direction – recruitment rate equal to death rate (Bybee, pers. comm., 2012). Feral horses have not shown any problems reproducing and are not currently a management concern due to the control efforts already in place (Bybee, pers. comm., 2012).

<u>Threats and Stressor Factors</u>

The main stressor to PMWHR feral horses is range condition (availability of forage, water availability). Availability of grazing land and forage habitat is essential for maintaining stable wild horse populations in the PMWHR.

Photo 7. Wind erosion in the National Park inventory unit. Image reproduced from Ricketts et al. (2004).

Ricketts et al. (2004) notes that increases in the proportion of rock to bare soil would be an indication of range decline, as erosion plays a big part in the availability of forage land. Ricketts et al. (2004) found that PMWHR exhibited severe signs of erosion and losses of native plant communities. Water and wind erosion (Photo 7) are both major concerns within the PMWHR, especially in areas of sparse vegetation, high winds, and heavier rainfall. Erosion is readily apparent in the NPS inventory unit; 31 percent of transects examined by Ricketts et al. (2004) exhibited significant soil erosion. Continued high rates of erosion could promote pedestaling and deterioration of grazing habitat. Areas under heavy grazing pressure tended to show higher rates of soil erosion with losses of over 76 cm (2.5

feet) in the NPS inventory unit (Ricketts et al. 2004). Ricketts et al. (2004) recommended a grazing rotation, allowing for vegetative recovery in areas of high soil loss. The newly installed guzzlers are expected to mitigate several of the problems regarding forage habitat and water availability, encouraging horses to look for forage in previously under-grazed areas (Mullen 2011).

Data Needs/Gaps

Much of the information provided concerning PMWHR condition comes from Ricketts et al. (2004), a study which is nearly 10 years old. It is uncertain whether significant changes in condition have occurred within that time period; therefore, these changes may not be fully reflected in the condition assessment. A newer study re-evaluating the sample plots from Ricketts et al. (2004) might be used to better evaluate overall PMWHR condition, although according to Bybee (pers. comm., 2012), condition since the 2004 study would likely remain static.

Overall Condition

BICA staff assigned the measures of forage, water, and population size a *Significance Level* of 3 and the measures of cover and space and herd health a *Significance Level* of 2.

Population Size (*Appropriate Management Level*)

The BICA population size measure was assigned a *Condition Level* of 1. The population, as of February 2012, is 156 adult horses and 18 foals, above the BLM AML upper limit of 120 individuals. There is no concern that the population size is too low, but with a high population comes increased stress on resources that the horses utilize within the range. Removal efforts are expected to occur in 2012, with excess PMWHR wild horses being put up for "adoption." Wild horse populations will continue to be monitored by the BLM (BLM 2012).

Water Availability

The water availability measure was assigned a *Condition Level* of 2. This measure is currently of moderate concern to resource managers, showing pronounced signs of degradation. In the BICA portion of the PMWHR, water is occasionally plentiful but often limited in supply. Stresses may emerge depending on water availability during the winter months due to absence of snow or icing-over of water sources. Construction of guzzlers within the PMWHR in 2010 will add to water availability and encourage horses to use previously under-utilized habitat.

Forage Availability

The forage measure was assigned a *Condition Level* of 3. This measure is currently of great concern to resource managers, showing significant signs of degradation. Rangeland was found to be at risk, in the "unhealthy" category based on site and similarity indices (Ricketts et al. 2004). Recently, vegetation was low in similarity to potential vegetation and not reflective of the HCPC (Ricketts et al. 2004). A similarity index of 44% and site index of 2.25 out of 5 were determined for the National Park portion of the PMWHR, indicating significant deviation from HCPC and ideal forage habitat. Daubenmire plot results showed a downward trend in the status of native plant communities in the Mustang Flat plot of the PMWHR.

Cover and Space Availability
The cover and space measure was assigned a *Condition Level* of 1. This measure is currently of low concern to resource managers, showing slight signs of degradation. Cover is not currently seen as a management issue of concern. Open space has been limited by Secretarial Order, the Wild Free-Roaming Horse and Burro Act. Dense tree growth has been negatively affecting populations and horses are occasionally found outside of the PMWHR. However, both are minor concerns. Cover in the NPS portion of the PMWHR is currently adequate for the number of horses present.

Herd Health (*Genetic Diversity, Reproductive Success*)
The BICA herd health measure was assigned a *Condition Level* of 1. This measure is currently of minor concern to resource managers, showing slight signs of degradation. Cothran (2010) reported no evidence of genetic drift or population bottlenecking. The 2011 recruitment rate of 11.5% was below the 17.5% expected by the BLM; however, heterozygosity was high – higher than previous genetic studies. The BLM goal is to have recruitment equal to mortality; this disparity is currently seen as a management issue of concern. The continued use of fertility control drugs such as PZP, with a goal of 80-85% treatment rate within the next 5 years, is encouraged in the PMWHR (BLM 2011).

Weighted Condition Score
The overall *Weighted Condition Score* (WCS) for the BICA wild horses component is 0.564, indicating the condition of this resource is of moderate concern. The trend in condition of this resource is declining, based on deteriorating range health and forage availability.

Wild Horses

Measures	SL	CL
• Population size (appropriate management level)	3	1
• Water availability	3	2
• Forage availability	3	3
• Cover and space vvailability	2	1
• Herd health (genetic diversity, reproductive success)	2	1

WCS = 0.564

Sources of Expertise
Jared Bybee, Rangeland Management Specialist–Montana/Dakotas State Wild Horse and Burro Specialist, Bureau of Land Management

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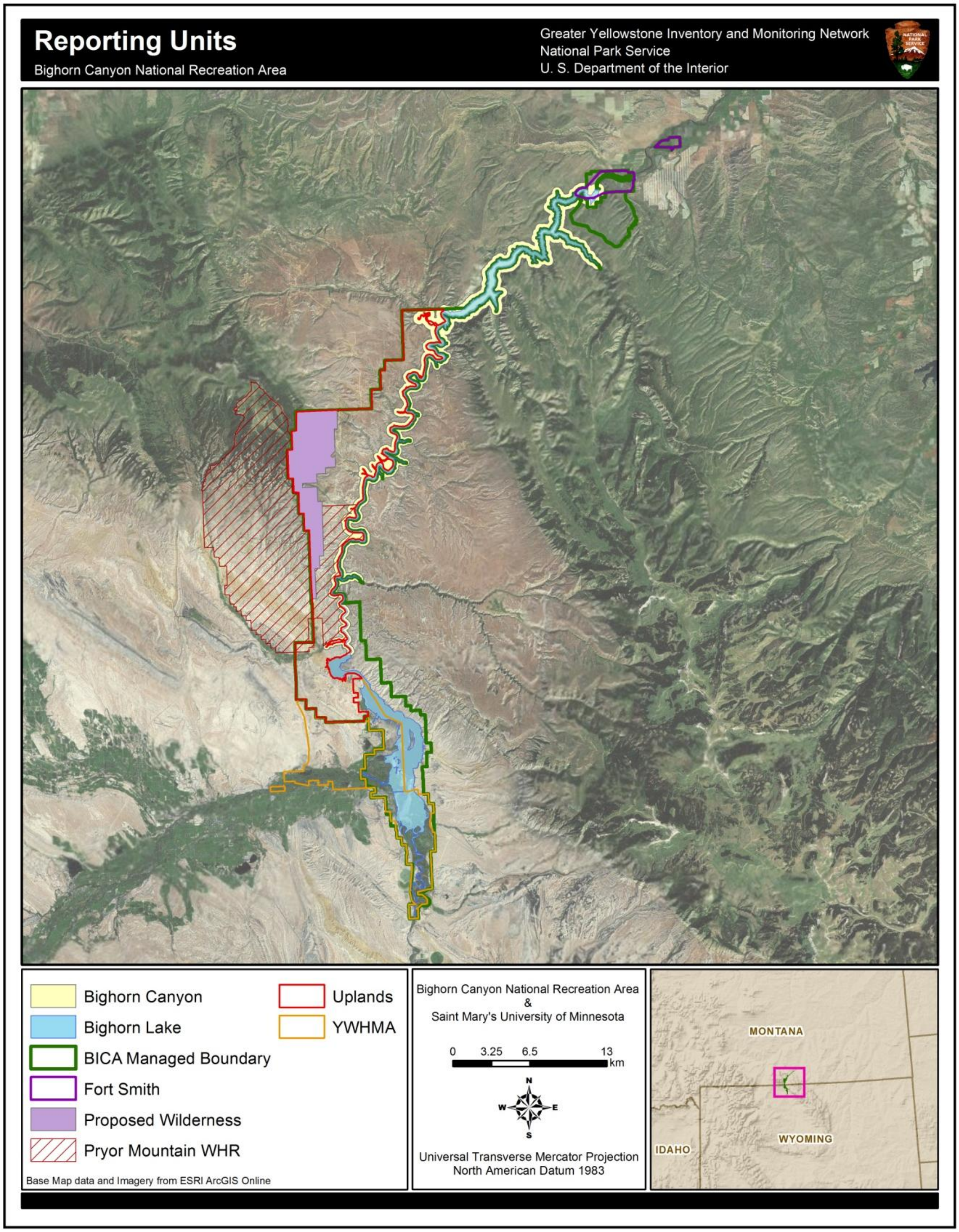


Plate 9. Administrative units within BICA, including PMWHR.

4.7 Bats

Description

Bat populations are important indicators of an ecosystem's overall health. They contribute to an ecosystem's overall biodiversity, they possess ecological and economic value as ecosystem components, and they are vulnerable to rapid population declines (O'Shea et al. 2003). These traits make monitoring trends in bat populations beneficial to management.

Photo 8. Big brown bat (NPS photo).

BICA exhibits the highest bat diversity of all parks in GRYN (Keinath 2007). At least 11 different species of bats utilize BICA; Keinath (2007) notes that the diversity in BICA is likely attributed to the abundance of various roosting habitats and the large expanses of still water for insect life and consumption. The most common species of bats in the park are the little brown bat (*Myotis lucifugus*) and the big brown bat (*Epesicus fuscus*).

Bat populations could decline for a number of reasons: roost destruction, habitat modification, diseases, and anthropogenic disturbances (Mattson 1994). Many species of bats in the United States form their largest aggregations during winter months when they hibernate in caves and mine tunnels (Barbour and Davis 1969). During these winter months, bat aggregations can number as high as 100,000 bats in a hibernaculum. When gathered in large colonies, bats are vulnerable to natural and anthropogenic threats (O'Shea et al. 2003). In addition, because bats exhibit low fecundity rates (Mattson 1994), their populations recover slowly from disturbance. Disturbance of maternity colonies are a particular concern, because such disturbance can suppress already low reproduction rates and, furthermore, these colonies require specific roost characteristics that can be limiting in the environment.

Measures

- Presence or absence of white-nose syndrome (WNS)
- Relative abundance
- Change in site occupation within the park unit
- Colonial roost abundance
- Environmental condition of colonial roosts

Reference Conditions/Values

Reference conditions for all measures in this assessment are unknown, with the exception of the white-nose syndrome (WNS) measure. For presence or absence of WNS, the reference condition is no occurrence of WNS.

Data and Methods

Doug Keinath (pers. comm., 2011) provided citations for appropriate resources regarding the measures used in this assessment. Keinath performed an inventory of bats for the Greater Yellowstone Network (Keinath 2005) and provided insight into the appropriate measures for this assessment.

Current Condition and Trend

Presence or Absence of White-nose Syndrome

In recent history, white-nose syndrome severely affected bats in the eastern U.S. The disease was discovered in four caves in Albany, New York in the winter of 2006-2007. Colonies of bats hibernating in these caves were well studied before the WNS outbreak and after the outbreak, so pre-WNS data was available, allowing experts to determine that WNS caused reductions of 81-97% of their population (USGS 2010).

Initially, scientists could not determine what was affecting bats in these cave colonies. In the summer of 2009, however, scientists identified a previously unknown species of cold-thriving fungus (*Geomyces destructans*). This fungus thrives in low temperatures (5-14°C) and high levels of humidity (>90%), conditions that are characteristic of the bodies of hibernating bats and the caves in which they hibernate. Although WNS was named for the obvious symptom of white noses on infected bats, the most vulnerable parts of the bats that are often infected are the wings (USGS 2010). Healthy wing membranes are vital to bats; wings make up about 85% of a bat's total body surface area. Wings help to regulate body temperature, water balance, and flight (USGS 2010).

Photo 9. Little brown bat with white-nose syndrome (USFWS photo by Ryan von Linden).

When infected with WNS, bats experience a disturbance in their hibernation arousal patterns. Typically, bats will store large amounts of fat prior to hibernation, and most of the energy that is stored is used during natural arousals throughout the winter. During these natural arousals, bats will consume up to 90% of their stored fat to warm up their body, urinate, drink, mate, re-stimulate their immune system, and relocate their roost within the colony (USGS 2010). When WNS irritates bats enough to bring them out of torpor, bats can run out of stored body fat and starve.

WNS is not present in Wyoming. However, as of May 2011, WNS occurred in 16 states (Connecticut, Indiana, Kentucky, Maine, Maryland, Massachussets, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Vermont, Virginia, and West Virginia) and in four Canadian provinces (New Brunswick, Nova Scotia, Ontario, and Quebec) (USFWS 2011). The fungus associated with WNS also exists in three additional states (Delaware, Missouri, and Oklahoma) (USFWS 2011). Among the species hardest hit by WNS are little brown bats, which are present in BICA. The sudden and widespread mortality associated with WNS is unprecedented for hibernating bats, among which widespread disease outbreaks have not been previously documented (USGS 2010). Controlling the spread of this disease is important and humans should exercise care if visiting multiple caves within the disease's range.

Relative Abundance

Keinath (2005) performed an inventory for all GRYN parks to determine the species composition and relative abundance of bats, both network-wide and for each individual unit. The goal of Keinath's study was to create extensive records of the bat fauna that utilize GRYN, with hopes of documenting 90% of bat species that occur in the parks. According to the results, BICA's bat fauna is the most diverse of all parks in GRYN, greater than Yellowstone National Park and Grand Teton National Park. Keinath (2005) concluded that BICA is "one of the hot-spots for bats in all of Wyoming and perhaps all of the northern Rocky Mountain States." Species with the greatest abundance in BICA are the little brown bat and big brown bat, designated as very high and high abundance, respectively. Other bat species documented in the park vary regarding relative abundance (Table 17).

Table 17. Bat species list for BICA (reproduced from Keinath 2005).

Species Name	Abundance[a]	Status Notes[b]
pallid bat (*Antrozous pallidus*)	Low	Localized
Townsend's big-eared bat (*Corynorhinus townsendii*)	Low-Medium	Localized
big brown bat (*Epesicus fuscus*)	High	Widespread
spotted bat (*Euderma maculatum*)	Medium	Localized
hoary bat (*Lasiurus cinereus*)	Low	Sparse but widespread
silver-haired bat (*Lasionycteris noctivagans*)	Uncertain	Questionable occurrence
California myotis (*Myotis californicus*)	Uncertain	Questionable occurrence
small-footed myotis (*Myotis cilioabrum*)	Medium	
long-eared myotis (*Myotis evotis*)	Medium	
little brown bat (*Myotis lucifugus*)	Very High	Common and widespread
fringe-tailed bat (*Myotis thysanodes*)	Low	Localized
long-legged myotis (*Myotis volans*)	Medium	
Yuma myotis (*Myotis yumanensis*)	Medium	
Species Richness for BICA	11-13	

[a] Abundance is noted using a categorical scale representing the author's subjective assessment from the data collected during this inventory. Low, medium, high, very high, and uncertain designations indicate unit-wide likelihood of occurrence and do not speak to population viability or relevance to broader distributions.

[b] Generally speaking, questionable (or uncertain) species have been identified only by passively collected ANABAT® recording, but have not been captured or otherwise identified in the park. These records should be considered tentative and in need of corroboration. The *Myotis californicus* in BICA was captured, but not conclusively identified (final determination will be made by museum experts).

Change in Site Occupation within the Park Unit

Keinath (2005) examined six specific sites in BICA: Layout Creek; BICA land near Yellowtail Wildlife Habitat Management Area (YWHMA); Hillsboro Ranch and beaver ponds; Lockhart

Ranch and beaver ponds; caves within or near BICA (including those on BLM land); and cliffs along the walls of Bighorn Canyon and Devil Canyon. Two of these sites were unique to both BICA and the larger GRYN. The Layout Creek site exhibited the highest species richness of all sites examined in GRYN; all 13 bat species in the network utilized this site during the study. This is most likely due to the multitude of habitat types in the immediate area. The YWHMA site is likely the most productive bat area in GRYN; there is an abundance of insect life in the area and many different foraging habitat types (e.g., open-water habitat, open grassland and shrubland, and cottonwood gallery forest).

Colonial Roost Abundance

Colonial roosting bats congregate into large groups within natural formations (e.g., caves, crevices) or man-made structures (e.g., mines, buildings, and bridges) to hibernate or raise young. In general, monitoring bat colonies is a difficult task, due to the variation in the ecology between different bat species (O'Shea et al. 2003). Some bats frequent the same roosts for long durations of time, while others will use a suite of roosts in a more erratic fashion (O'Shea et al. 2003). In addition, traditional in-cave bat surveys can compromise the health of bats, due to disturbance (O'Shea et al. 2003).

Keinath (2005) described the roosting habitat in the general vicinity of the park as abundant and diverse. Some of the different types of roosting habitat near the park include cliffs, caves, abandoned buildings, and mines. BLM land adjacent to the park hosts many caves, such as Horse Thief Cave, Bighorn Caverns, and Natural Trap Cave. Even though many roosting locations exist in and near the park, the abundance and usage patterns of bats within them is unknown.

Additional data sources regarding colonial roost abundance were discovered late in the assessment process and are identified in the data needs section.

Threats and Stressor Factors

Bats demand three unique habitat features: roosts, foraging areas, and open water. Bats depend on roosts for rest, safety from predators, raising young, and hibernation. Maternity and hibernating roosts are paramount for survival, because prime roosts of these types are scarce. Humans can both assist (e.g., building bat houses) and harm (e.g., destroying roosting trees) these habitats. Foraging areas with abundant concentrations of insects are also necessary. Human activities that reduce the abundance of insects, such as pesticide application or development, in turn alter bat community composition. Open and relatively still water is needed by bats for drinking, and helps support reproduction of insects that bats prey upon (Keinath 2007). Bats require all of these components in a landscape and the loss or degradation of one can make an area uninhabitable. In the future, climate change could change the aforementioned habitat features in BICA and is, therefore, a concern to park management (Bromley, pers. comm., 2012).

White-nose syndrome is also a prominent threat to bats in North America as described in earlier in this document.

Data Needs/Gaps

For this assessment, data from only one inventory of bats in the park exists. Future inventories in the park would provide valuable information for assessing condition and trend in the future. In addition, enough data to define condition based on three of the measures do not exist.

Doug Keinath (pers. comm., 2012) indicated that additional data could be available from the Wyoming Department of Game and Fish that are applicable to multiple measures in this assessment. However, attempts to contact identified individuals during development of this assessment were not successful.

The Montana Natural Heritage Program may also have data relevant to this topic, but this was unknown until late in the assessment process.

<u>Overall Condition</u>

Presence or Absence of White-nose Syndrome (WNS)
WNS is not present in Wyoming at this time, therefore the *Condition Level* of this measure (*Significance Level*=3) is 0, indicating little or no concern. Understanding the prevalence of WNS in the United States is a primary interest of many researchers, state resource departments, and federal agencies, because of the detrimental effects on bat populations. As WNS continues to spread west, the concern for BICA will be much greater in the future.

Relative Abundance
Keinath (2005) documented the relative abundance of bats within BICA and the other parks in GRYN. However, this information acts more as baseline data for future assessments and condition of this measure is unknown. Replication of Keinath's methods could allow for comparison and condition designation in the future, but in a very coarse sense (Keinath, pers. comm., 2012). Monitoring that expands on Keinath's methods to incorporate more quantitative metrics (e.g., captures per net hour or calls recorded per hour) would provide the most insight into condition based on this measure (Keinath, pers. comm., 2012).

Change in Site Occupation within the Park Unit
Keinath (2005) provided data regarding site occupation (*Significance Level*=2) within BICA at one instance. In order to define condition of this measure, additional monitoring is necessary. Repeated surveys of sites examined by Keinath (2005) and also additional sites within BICA throughout active seasons and over multiple years would provide the most clarity regarding this measure (Keinath, pers. comm., 2012).

Colonial Roost Abundance
Condition of bats in BICA according to this measure is currently unknown. Data on the locations of colonies and their abundance in the park were not available during this assessment. In addition, some of the data regarding roost abundance are sensitive and not available for dissemination to the public. Keinath (pers. comm., 2012) indicated that an unpublished report (Bogan and Geluso 1999) is available that could provide some information regarding this topic, but the report could not be acquired during this assessment.

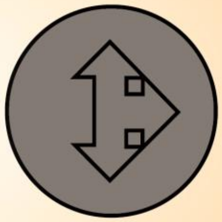
Environmental Condition of Colonial Roosts
No data or information regarding the environmental condition of roosts (*Significance Level*=1) are available.

Weighted Condition Score

Weighted Condition Score for this component is currently unknown. *Condition Level* is known for only one measure at this time: presence or absence of WNS. Until additional data and literature are available for other measures, the condition of bats in BICA will be unknown.

Bats

Measures	SL	CL
Presence/absence of WNS	3	0
Change in site occupation in park	2	n/a
Relative abundance	3	n/a
Colonial roost abundance	3	n/a
Environmental condition of colonial roosts	1	n/a



WCS = N/A

Sources of Expertise

Doug Keinath, Biologist, Wyoming Natural Diversity Database

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4.8 Game Birds

Description

Unlike most NPS units, most of BICA is open to public hunting during the established hunting seasons and in accordance with state hunting regulations. While often overshadowed by big game species, Wyoming is home to a great variety of migratory game birds and both native and introduced upland game bird species (WGFD 2011, Appendix E).

Photo 10. Wild turkey. Photo by Bill Garland, USFWS.

Most game bird hunting in the park occurs in the Yellowtail Wildlife Habitat Management Area (YWHMA), which is managed through a Cooperative Resource Management agreement between the Wyoming Game & Fish Department (WGFD), the Bureau of Reclamation (BOR), NPS, Bureau of Land Management (BLM), and private landowners. This group has done significant work in habitat improvement for game birds and other species. Groups such as the National Wild Turkey Federation are also contributing to habitat work in the YWHMA.

Common, popular game bird species in the BICA area include the wild turkey (*Meleagris gallopavo*) (Photo 10), ring-necked pheasants (*Phasianus colchicus*), various waterfowl species, sandhill cranes (*Grus canadensis)*, and mourning doves (*Zenaida macroura*) (WGFD 2011). The majority of the wild turkeys in the state are the Merriam’s subspecies (*M. g. merriami*), but some of the Rio Grande subspecies (*M. g. intermedia*) occur in cottonwood bottomlands in the state. Rio Grande turkeys have been stocked in BICA in the past, and any turkeys currently in BICA are likely hybrids between the Rio Grande and Merriam’s subspecies (Easterly, pers. comm., 2012).

Pheasants exist in natural (non-supplemented) populations in the state; however, the WGFD operates two production facilities and releases pheasants in popular hunting areas (WGFD 2011). During most years, the WGFD releases 3,000-4,000 pheasants from these production facilities into the Yellowtail Wildlife Habitat Management Area (an area that includes BICA) (Easterly, pers. comm., 2012). Monitoring of both the game bird species’ abundance and harvest data could indicate the overall health of the populations, the quality of hunting in BICA and the surrounding area, and the sustainability of the ecosystems on which the species depend.

Measures

- Turkey abundance
- Take per unit effort

- Pheasant abundance
- Waterfowl abundance
- Sandhill crane abundance
- Mourning dove abundance
- Habitat suitability
- Number of ponds with water per year

Reference Conditions/Values

Reference conditions for the defined measures of this component are unavailable. In general, some data exist for all measures, but we are unable to make quantitative comparisons that explicitly define condition at this time. Data and information synthesized in this document could be used as a reference condition for similar assessments in the future.

Data and Methods

The NPS Certified Bird Species List (NPS 2011) for BICA was used for this assessment. This list includes all of the confirmed bird species present in the park. For this component, only bird species considered game birds (as defined by USFWS 2011, and Easterly, pers. comm., 2012) were included. SMUMN GSS removed all other bird species from this list, as these species are discussed separately in Chapter 4.9 of this document.

The Kane, WY, Christmas Bird Count is part of the International Christmas Bird Count (CBC), which started in 1900 and is coordinated internationally by the Audubon Society. The Kane, WY, CBC is near BICA (the count extends into BICA's boundaries), and has been conducted annually since 1991. Multiple volunteers survey a 24-km (15-mi) diameter on one day, typically between 14 December and 5 January. The center point of the 24-km diameter is the historic town of Kane, WY (44-50'37" N, 108-12'10" W) (Plate 10).

The BICA breeding bird survey route is part of the large-scale North American Breeding Bird Survey (BBS), which began in 1966. The United States Geological Survey (USGS) and the Canadian Wildlife Service coordinate the annual BBS efforts across the continent (Robbins et al. 1986). The standard BBS route is approximately 40 km (25 mi) long with survey points at every 0.8 km (0.5 mi). The survey begins one-half hour before sunrise, and at each survey point volunteers record the number of birds seen and heard within a 0.4-km (0.25-mi) radius during a three-minute interval. Only BBS route 92037 (Lovell Route) crosses within the park boundaries (Plate 11). This route was surveyed annually from 1989-2007 (USGS 2011).

The WGFD compiles annual reports of small and upland game species harvest. These annual reports use data obtained from voluntary hunter surveys and are estimates of total harvest, not actual harvest statistics. The 2008-2010 annual reports (WGFD 2008, 2009, 2010) were used to report annual harvest of the game species found in BICA.

Current Condition and Trend

Turkey Abundance

No survey that focuses exclusively on wild turkeys exists in BICA, although some auditory survey data exist from the annual pheasant survey. In order to report a coarse overview of annual wild turkey abundance, data from the yearly BBS and CBC efforts in BICA were used. These surveys provide some information on annual wild turkey abundance, but they are not optimal surveys/data sources to base estimate turkey abundance, as they do not occur at optimal turkey observation times/seasons. The first record of a wild turkey during either the BBS or the CBC in the park was in 1991 (one observed on the BBS, one observed on the CBC) (Figure 9). Observations have been sporadic in the park, with most observations coming from the 2004 (18), 2007 (19), and 2008 (11) CBCs (Figure 9).

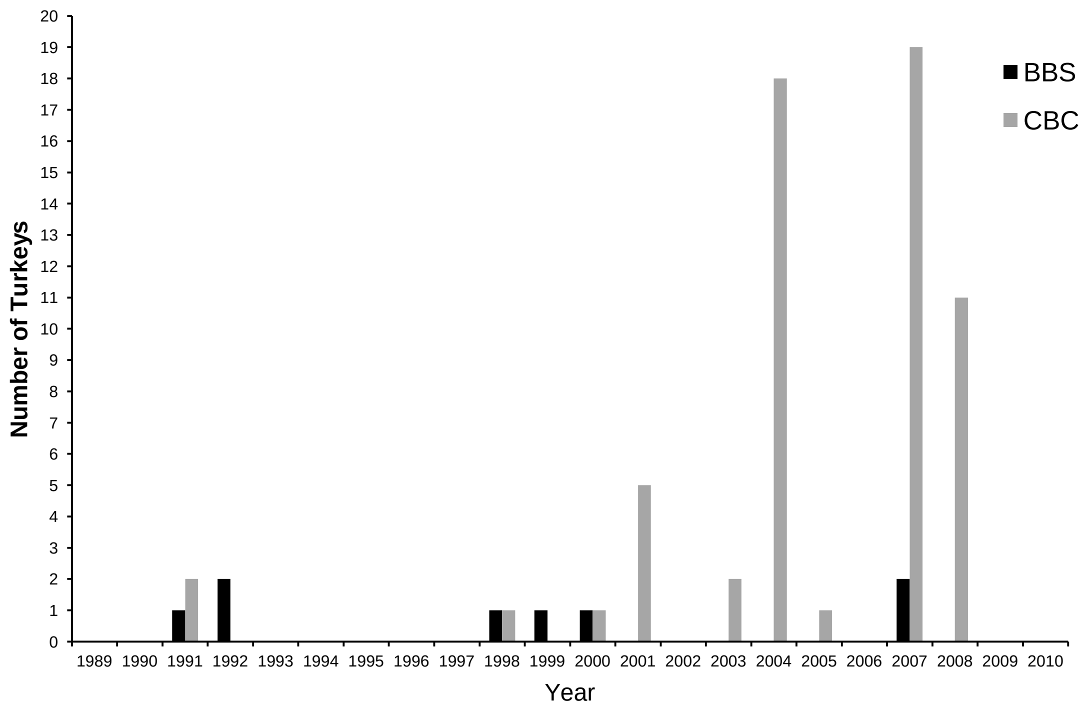


Figure 9. Number of wild turkey observations during the BICA BBS and CBC efforts from 1989-2010 (USGS 2011, NAS 2012). Note that the BBS has not occurred in BICA since 2007.

Take per Unit Effort

Wild Turkey

Wyoming has two wild turkey hunting seasons, with one season in the spring and one season in the fall of each year (WGFD 2011). Wyoming is divided into 14 turkey management areas; BICA lies within turkey management area 6. This management area has typically had only one turkey hunting season that occurs in the spring (generally mid-April until late-May) (WGFD 2010). In 2011, turkey management area 6 had its first fall hunting season, and another fall hunting season is scheduled for 2012 (Easterly, pers. comm., 2012). The Yellowtail Wildlife Habitat Management Area (adjacent to BICA) is one of the most popular turkey hunting regions in turkey management area 6, and is open for turkey hunting only to hunters with a Type 1 license.

During the hunting season, hunters may only take male wild turkeys, or any wild turkey that has a visible beard (WGFD 2010). The bag limit for a season is one wild turkey for all licensed hunters, and each season has a set number of permits that are awarded. In 2011, 50 permits were awarded for both license type 1 and 2 hunts (Table 18). Take of legal turkeys must be by means of firearms using center-fire cartridges, muzzle-loading firearms, 0.22 caliber firearms, or archery equipment (WGFD 2011). Hunters may only shoot during legal shooting hours (shooting may begin one-half hour before sunrise and will end at sunset) (WGFD 2010).

From 2008-2011, the average number of harvested wild turkeys in turkey management area 6 was 27.38 (Table 18). During this same time, the average number of hunter days was 174.63. The average take per unit effort (harvest per hunter days) in turkey management area 6 was 0.20 (Table 18). These statistics apply to all of turkey management area 6, and are not limited to BICA. Because of this, the harvest statistics for BICA are different from what is displayed in Table 18.

Table 18. Annual wild turkey spring harvest estimates for turkey management area 6 in Wyoming (WGFD 2008, 2009, 2010).

Year	License Type	Permits per Regulation	# of Hunters	Toms	Hens	Total Harvest	Success Rate	Hunter Days	Harvest per Day
2008	1	30	28	18	0	18	64.29%	124	0.15
	2	40	40	20	0	20	50.00%	115	0.17
2009	1	40	34	29	0	29	85.30%	118	0.25
	2	50	42	30	0	30	71.00%	132	0.23
2010	1	40	42	29	0	29	72.80%	141	0.21
	2	50	50	33	0	33	81.90%	337	0.10
2011	1	50	51	36	0	36	75.20%	199	0.18
	2	50	47	24	0	24	51.10%	231	0.10
Averages	**-**	**-**	**41.75**	**27.38**	**0**	**27.38**	**69.00%**	**174.63**	**0.20**

Ring-necked Pheasant

From 1982-2009, Wyoming was divided into 46 pheasant management areas. In 2010, the state management areas were redefined, and six new pheasant management areas now exist; BICA lies within pheasant management area 2 (WGFD 2010). Because of this, the harvest data for the BICA region will differ significantly when comparing pre-2010 and post-2010 estimates (post-2010 data has higher harvest rates than were seen before the realignment).

Hunting season for these hunt areas typically begins in early November and ends in late December (the 2011 pheasant season ran from 5 November – 31 December). For most parts of the BICA area, shooting hours begin one-half hour before sunrise and end at sunset. However, at the Yellowtail Wildlife Habitat Management Area, weekday shooting hours are from 11:00am until sunset; this delay allows the WGFD to plant pheasants in this area (Easterly, pers. comm., 2012). The daily bag limit in this region is three male pheasants, while the possession limit for pheasants is nine. A portion of land north of the Shoshone River and west of the Yellowtail Reservoir is open to any pheasant take (male or female) (WGFD 2010).

From 2008-2010, the average number of ring-necked pheasants harvested in pheasant management area 2 (of which BICA comprises a small part) was 7,652 (Table 19). During this same time, the average number of hunter days was 8,045. The average take per unit effort (harvest per hunter days) for pheasants in this region was 1.02 (Table 19). Following the realignment of pheasant management areas in Wyoming, the BICA region experienced an increase in all categories of Table 19. These harvest statistics are for all areas of pheasant management area 2, and are not restricted to the BICA boundaries. The actual harvest in BICA is substantially different from what is reported in Table 19.

Table 19. Number of ring-necked pheasant hunters, harvest estimates, and take per unit of effort (harvest/days) in pheasant management area 2 from 2008-2010 (WGFD 2008, 2009, 2010).

Year	Hunters	Harvest	Days	Harvest/Day
2008	979	5,698	4,465	0.86
2009	1,111	5,889	6,433	0.92
2010	2,507	11,369	13,237	1.28
Average	**1,532**	**7,652**	**8,045**	**1.02**

Waterfowl

Waterfowl, as defined by the WGFD, includes all geese and ducks (Anatidae family), American coots (*Fulica americana*), and mergansers (*Mergus* spp.) (WGFD 2010). BICA lies within waterfowl management area 4A, which is one of the major waterfowl harvest areas in Wyoming (WGFD 2008, 2009, 2010).

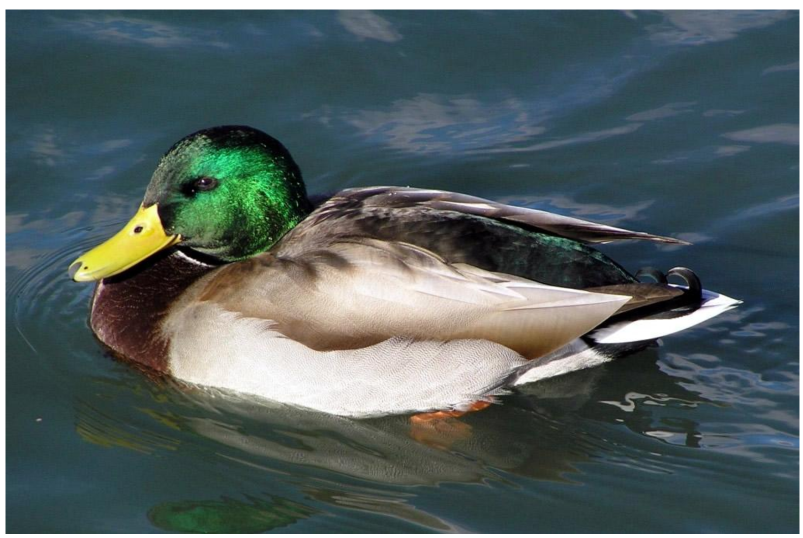


Photo 11. Mallard (NPS Photo).

Waterfowl hunting seasons vary by species, as geese have three open hunting periods and ducks have only two. Legal goose hunting periods (using 2011 dates) are from 2 October to 19 October, 6 November to 5 December, and again from 11 December to 5 February. Hunting hours are from one-half hour before sunrise until sunset. The daily bag limit for geese is five, with a possession limit of 10.

Duck season (ducks, mergansers, and coots in 2011) runs from 2 October to 19 October, and from 30 October to 16 January (WGFD 2010). The daily bag limit for coots is 15, with a possession limit of 30, while the daily bag limit for mergansers is five, with a possession limit of 10. Merganser hunters may not possess more than two hooded mergansers (*Lophodytes cucullatus*).

The daily bag limit for ducks is six, and may include any combination of species provided they meet the following restrictions:

- no more than five mallards (*Anas platyrhynchos*) (Photo 11), and no more than one hen;
- no more than one canvasback (*Aythya valisineria*);
- no more than two northern pintails (*Anas acuta*);
- no more than three wood ducks (*Aix sponsa*);
- no more than two redheads (*Aythya americana*);
- no more than two scaup (*Aythya affinis* or *A. marila*) (WGFD 2010).

From 2008-2010, the average number of geese harvested in waterfowl management area 4A was 6,258, and the average number of hunter days was 6,026 (Table 20). The average take per unit effort (harvest per days) of geese in this area was 1.04 (Table 20).

Table 20. Combined early and late season goose harvest in waterfowl management area 4A in Wyoming (WGFD 2008, 2009, 2010).

Year	Hunters	Harvest	Days	Harvest/Day
2008	982	5,595	6,533	0.86
2009	895	4,988	5,177	0.96
2010	955	8,191	6,367	1.29
Average	**944**	**6,258**	**6,026**	**1.04**

During the same period (2008-2010), the average number of ducks (including all coot, duck, and merganser harvest) harvested in waterfowl management area 4A was 37,631 (Table 21). The average number of hunter days during this time was 22,474 (Table 21). The average take per unit effort (harvest per days) of ducks was 1.70 (Table 21). Harvest estimates are different within BICA boundaries, and Table 21 represents duck harvest for all of waterfowl management area 4A.

Table 21. Duck, coot, and merganser harvest in waterfowl management area 4A in Wyoming (WGFD 2008, 2009, 2010).

Year	Hunters	Harvest	Days	Harvest/Day
2008	1,384	14,858	8,249	1.80
2009	1,339	12,537	7,824	1.60
2010	1,045	10,236	6,401	1.60
Average	**3,768**	**37,631**	**22,474**	**1.70**

Pheasant Abundance

Wild ring-necked pheasants can be found in many of Wyoming's agricultural regions. The major populations are located in the southeast portion of the state, the Lander/Riverton area, near irrigation projects in the Big Horn Basin, and in areas east of the Big Horn Mountains near the town of Sheridan (WGFD 2011). To supplement natural pheasant populations, the WGFD operates two pheasant production facilities. These facilities release birds in popular hunting areas, as well as walk-in hunting areas across the state (WGFD 2011).

A pheasant survey in the Yellowtail Wildlife Habitat Management Area has been conducted each year from 1969-1985, 1994, and from 2003-present (data are current only through 2010 for this assessment) (WGFD 2012b). This survey consists of 12 listening stations (Plate 12); a surveyor stops for 2 minutes at each station and records all pheasant crows and cackles that are heard (Easterly, pers. comm., 2012). Turkey gobbles are also recorded, but these data are not reported in this assessment.

Over the duration of the survey, the highest peak and average crow counts occurred prior to 1973 (Figure 10). The lowest peak and average crow counts occurred in 2003 (41 peak, 22.57 average) (Figure 10).

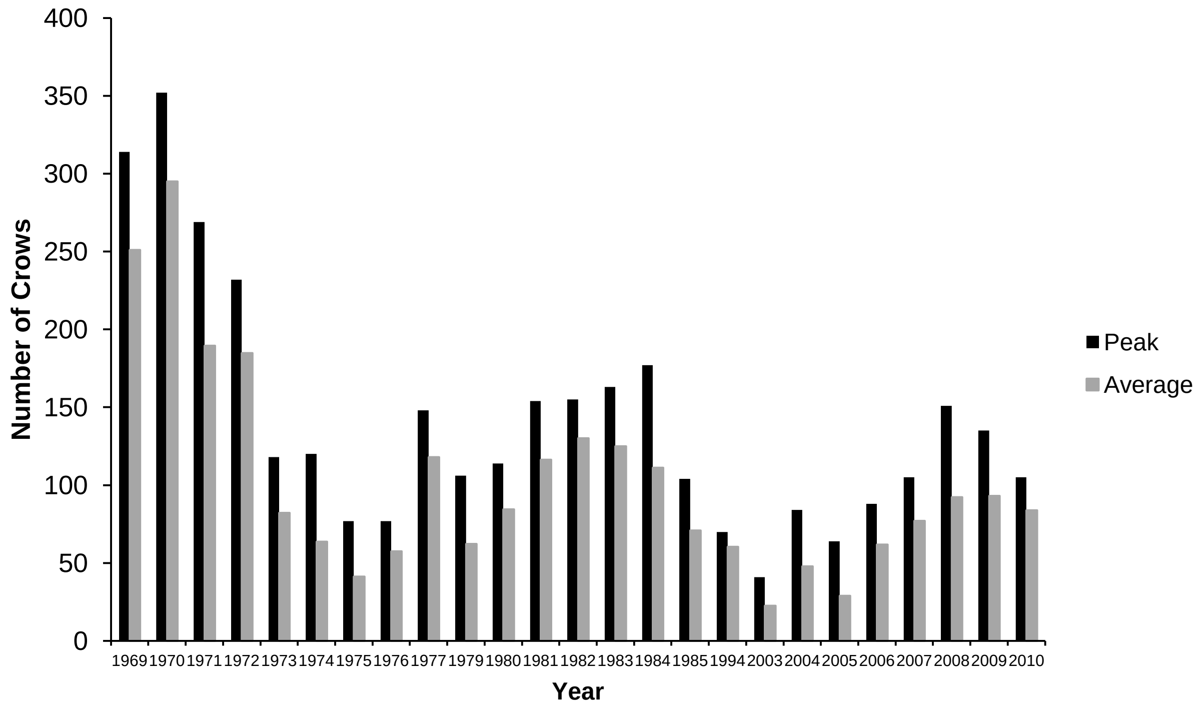


Figure 10. Annual ring-necked pheasant crow count data: peak and average values from 1969-1985, 1994, and 2003-2010. Data provided by Tom Easterly, Wildlife Biologist, Wyoming Game & Fish Department)

While these data are nearly continuous, the survey type contains several sources of potential biases (weather and moon phases influence how often pheasants call) and may not represent the best source of data to compare trend to (Easterly, pers. comm., 2012).

<u>Waterfowl Abundance</u>

As mentioned previously, the term waterfowl includes all geese, ducks, coots, and mergansers. While no formal survey exists for waterfowl in BICA, some species of waterfowl are detected on the park’s annual BBS and CBC efforts.

Waterfowl Detected on the BICA Breeding Bird Survey

From 1989-2007, eight different waterfowl species were detected on the BICA BBS (Plate 15): Canada goose, mallard, blue-winged teal, cinnamon teal, canvasback, lesser scaup, common merganser, and ruddy duck. Mallard and Canada goose (*Branta canadensis*) observations were the most frequent, accounting for approximately 95% of all observations. Figure 11 displays the total number of all waterfowl observed per year on the BICA BBS route.

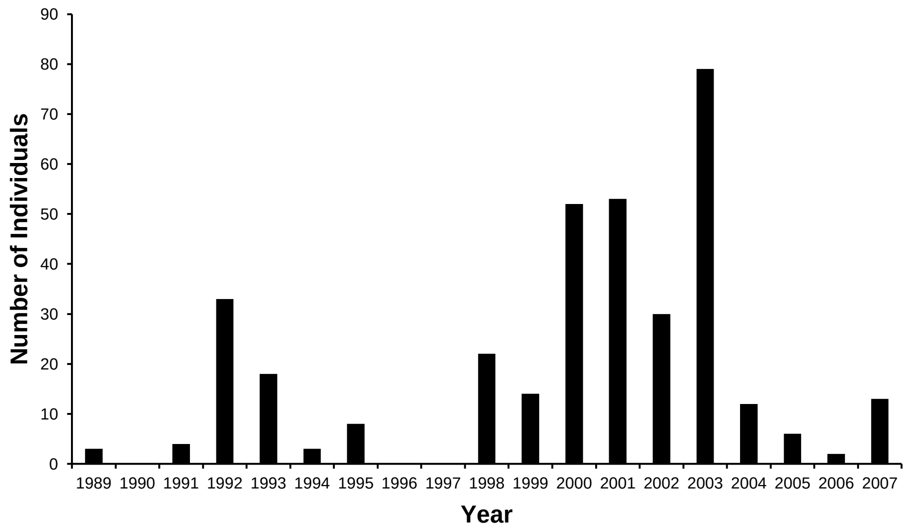


Figure 11. Number of waterfowl (individual birds) detected from 1989-2007 during BICA's BBS (USGS 2011).

Waterfowl Detected on the BICA Christmas Bird Count

The CBC presents a less reliable estimate of waterfowl abundance, as most ducks have migrated out of northern Wyoming by the time the CBC is conducted (Easterly, pers. comm., 2012). From 1991-2010, eleven species of waterfowl were observed during the BICA CBC (Table 22).

Table 22. Waterfowl species observed from 1991-2010 on the BICA CBC (NAS 2012).

Common Name	Latin Name
wood duck	*Aix sponsa*
northern pintail	*Anas acuta*
American wigeon	*Anas americana*
green-winged teal	*Anas crecca*
mallard	*Anas platyrhynchos*
lesser scaup	*Aythya affinis*
Canada goose	*Branta canadensis*
common goldeneye	*Bucephala clangula*
Barrow's goldeneye	*Bucephala islandica*
snow goose	*Chen caerulescens*
common merganser	*Mergus merganser*

Figure 12 displays the total number of all waterfowl observed per year during the BICA CBC route. Similar to the BBS data, over 95% of the waterfowl observations were either Canada goose or mallard. Figure 13 displays the total number of Canada goose and mallard observations per year.

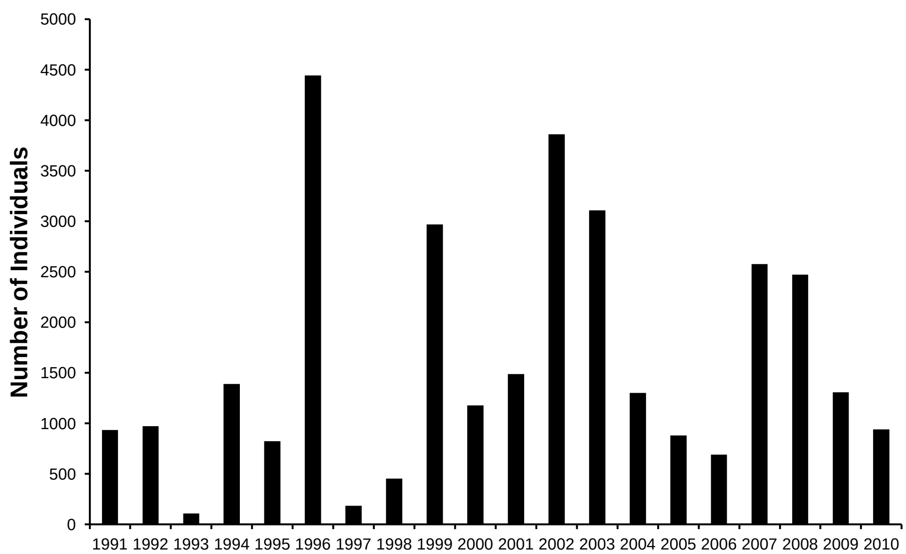


Figure 12. Number of waterfowl (individual birds) detected from 1991-2010 during BICA's CBC (NAS 2012).

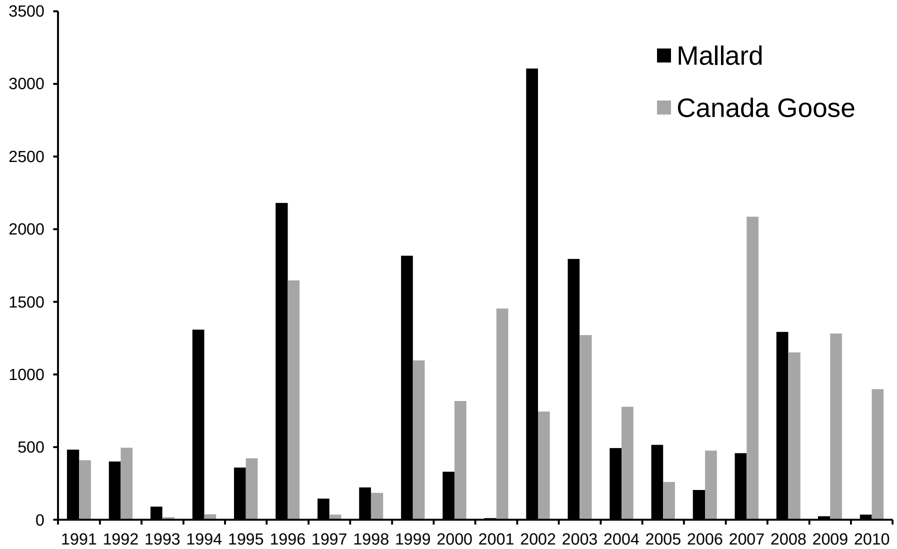


Figure 13. Canada goose and mallard observations from 1991-2010 during the BICA CBC (USGS 2011).

Habitat Suitability

To date, there has been no monitoring of habitat suitability in BICA.

Number of Ponds with Water per Year

The ponds in YWHMA provide habitat to a variety of game species, but fluctuations in water levels causes variability in the water available in the ponds. Various data sources exist that identify open water in the park (i.e., National Wetlands Inventory data, landcover data sets, and the park vegetation map), but these data sources do not provide a yearly account of the variation in available open-water habitat at critical times for game birds in the park. In addition, various aerial photography exists that could be georectified and analyzed to provide insight into the variation of water availability.

Threats and Stressor Factors

One of the major threats facing bird populations across all habitat types is land cover change (Morrison 1986). Land cover change is not restricted to breeding habitat; many species depend on specific migratory and wintering habitat types. Altered habitats can compromise the reproductive success or wintering survival rates of species adapted to that habitat. Invasive species such as Russian olive and tamarisk are big drivers of habitat alteration. Game bird species in BICA, such as the wild turkey and ring-necked pheasant, often require specific vegetative communities for successful nesting to occur. A loss or alteration of these vegetative structures could compromise the nesting success of these species in BICA and could lead to lower harvest rates for hunters.

West Nile Virus (WNV) can cause significant mortality in avian species (WGFD 2012). In Wyoming, sage grouse (*Centrocercus urophasianus*) have been particularly susceptible to WNV infection; significant mortality events have been documented in the Powder River Basin. In 2003 (the last WNV report available from WGFD), 19 sage grouse (Photo 12) died as a result of WNV infection; one of these 19 birds was found in Big Horn County (WGFD 2012a). However, no instances of WNV have been reported in sage grouse in BICA.

Photo 12. Sage grouse (NPS Photo).

Overharvest is unlikely to be a threat to the game bird population of BICA, as the hunting regulations, permit numbers, and daily bag limits are established and monitored by the WGFD. However, poaching could be a threat to the game bird population in the park; Wyoming and NPS enforcement officers monitors this threat through regular patrols.

<u>Data Needs/Gaps</u>
Breeding bird surveys and Christmas bird counts provide snapshots-in-time of species abundance. However, only one survey/visit per year yields little information in terms of abundance trends. Further observation could help to remedy this data gap and could potentially help the park better understand the status of game bird species in the park as well. BBS route 92037 (Lovell) was surveyed annually from 1989-2007. Resuming this survey, despite its limited coverage of BICA, would be beneficial for future analysis.

The establishment of species-specific surveys (notably wild turkey and ring-necked pheasant) would allow for more precise estimates of abundance in the park. Currently, the only estimates of abundance in BICA have come from CBC and BBS surveys. An appropriately timed and located survey for these specific species could provide park managers with an accurate estimate of population size and abundance of these species. Furthermore, monitoring of the harvest statistics within BICA’s administrative boundaries would provide managers with a more accurate representation of the harvest statistics for game birds in the park. Without these specific monitoring efforts, determining trends in the game bird populations and analyzing the current condition of these birds is impractical.

<u>Overall Condition</u>

Turkey Abundance
BICA staff assigned the measure of turkey abundance a *Significance Level* of 3. However, a *Condition Level* cannot be assigned for this measure at this time.

Direct estimates of wild turkey abundance using only BBS and CBC data are impractical due to the potential survey biases in roadside locations, CBC observers, and timing of surveys. In addition, the BBS only surveys a small portion of the park and may not provide an accurate representation of turkey abundance in BICA. Without a species specific survey effort, the current condition of this measure cannot be determined.

Take per Unit Effort
The measure of take per unit effort for BICA game birds was assigned a *Significance Level* of 2. A *Condition Level* for this measure was not assigned due to the lack of BICA specific harvest data. Harvest data exists for the BICA area, but these data cover a large geographic area and may not be representative of the hunter success rates found inside of BICA. While current estimates of hunter success in the area indicate consistent harvest rates and take per unit effort, no data exists for the area within BICA's administrative boundaries.

Pheasant Abundance
Pheasant abundance was assigned a *Significance Level* of 2. As a non-native species important to hunters, pheasants present an interesting management challenge. While CBC and BBS data could provide some estimate of pheasant abundance, there are potential biases (similar as listed above with wild turkey abundance) that make assessing condition using these data impractical. Furthermore, the annual crow count in BICA only takes into consideration vocalizing birds, and may not accurately assess the abundance in the park. There are also weather-related biases that may limit the effectiveness of this survey. For these reasons, the measure was not assigned a *Condition Level*.

Waterfowl Abundance
BICA staff assigned the measure of waterfowl abundance a *Significance Level* of 2. The only data that exist for the park come from the annual BBS and CBC efforts. These surveys are often conducted along a road or existing trail and may not accurately capture wetland areas where waterfowl are present. WGFD indicates that the BICA area is one of the prime waterfowl hunting areas in the state; a park-specific survey could help managers better estimate waterfowl species abundance and population sizes. No *Condition Level* was assigned to this measure.

Sandhill Crane Abundance
Sandhill crane abundance was assigned a *Significance Level* of 1. Similar to the above measures, the only data regarding this measure comes from the annual BBS and CBC efforts. Most observations occurred during the BBS, with 13 birds being seen in 1993. Birds were observed only one time during the BICA CBC. This is likely due to the fact that this bird is a migratory species and does not typically overwinter in the BICA region. Without the establishment of annual sandhill crane surveys, a *Condition Level* cannot be assigned to this measure.

Mourning Dove Abundance
The measure of mourning dove abundance was assigned a *Significance Level* of 1. The mourning dove was consistently observed on the BICA BBS from 1989-2007, and sporadically observed on the BICA CBC. Harvest estimates for the BICA region exist, but are not specific to the administrative boundaries of the park. No formal survey for mourning doves exists in the park. A *Condition Level* was not assigned to this measure due to a lack of BICA specific data.

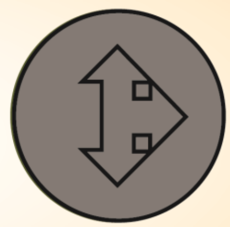
Habitat Suitability
BICA staff assigned the measure of habitat suitability a *Significance Level* of 3. However, no data exist for this measure and a *Condition Level* cannot be assigned.

Number of Ponds with Water per Year
The number of ponds with water per year measure was assigned a *Significance Level* of 2. No data exist for this measure, and no *Condition Level* was assigned.

Weighted Condition Score
A *Weighted Condition Score* (WCS) for game birds in BICA was not assigned because of a lack of BICA-specific data. Monitoring of these measures within the park boundaries would allow for a WCS to be assigned in the future.

Game Birds

Measures	SL	CL
• Turkey Abundance	3	n/a
• Take per Unit Effort	2	n/a
• Pheasant Abundance	2	n/a
• Waterfowl Abundance	2	n/a
• Sandhill Crane Abundance	1	n/a
• Mourning Dove Abundance	1	n/a
• Habitat Suitability	3	n/a
• # Ponds with Water/Year	2	n/a



WCS = N/A

Sources of Expertise
Tom Easterly, Wildlife Biologist, Wyoming Game & Fish Department

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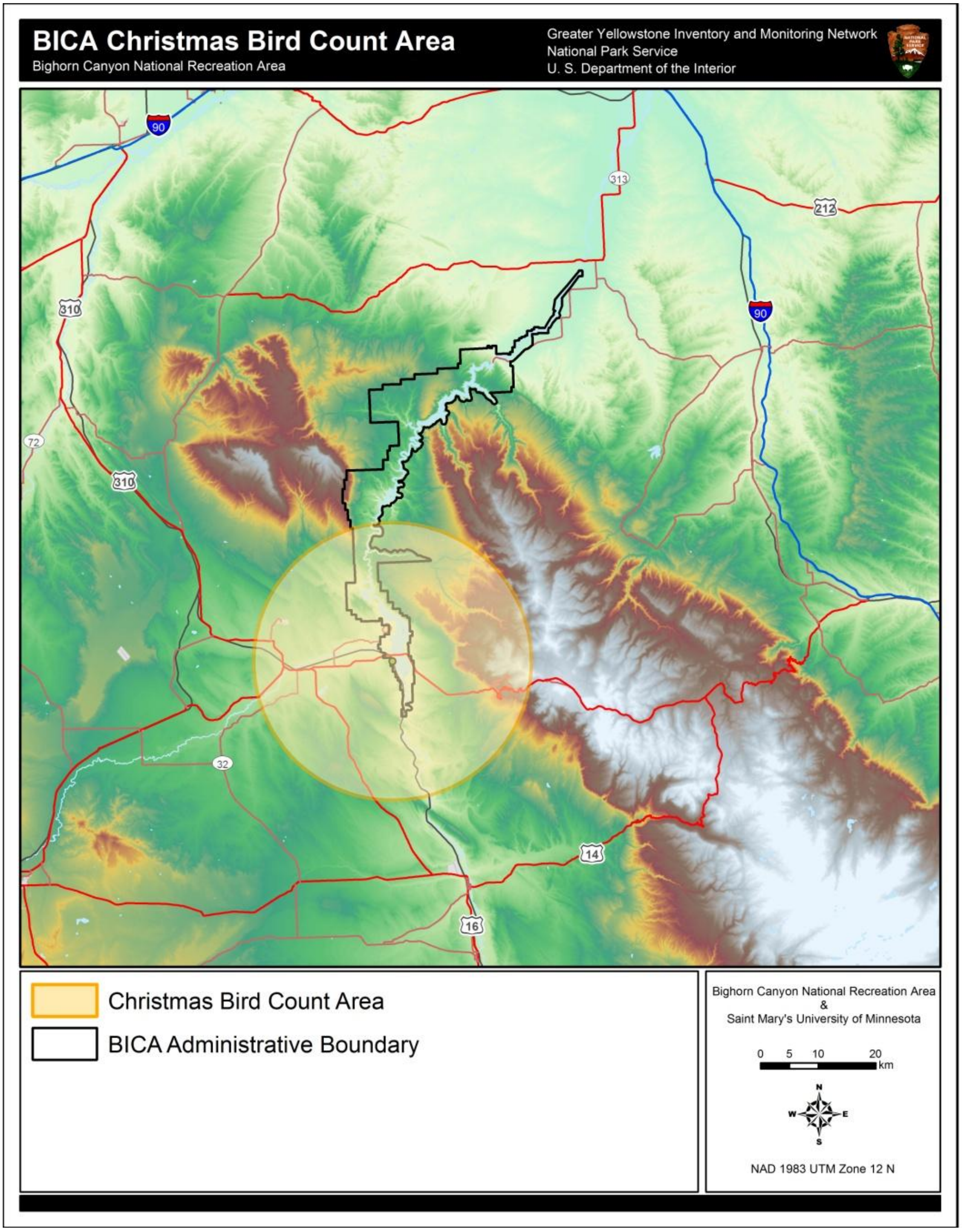

Plate 10. BICA Christmas Bird Count survey area.

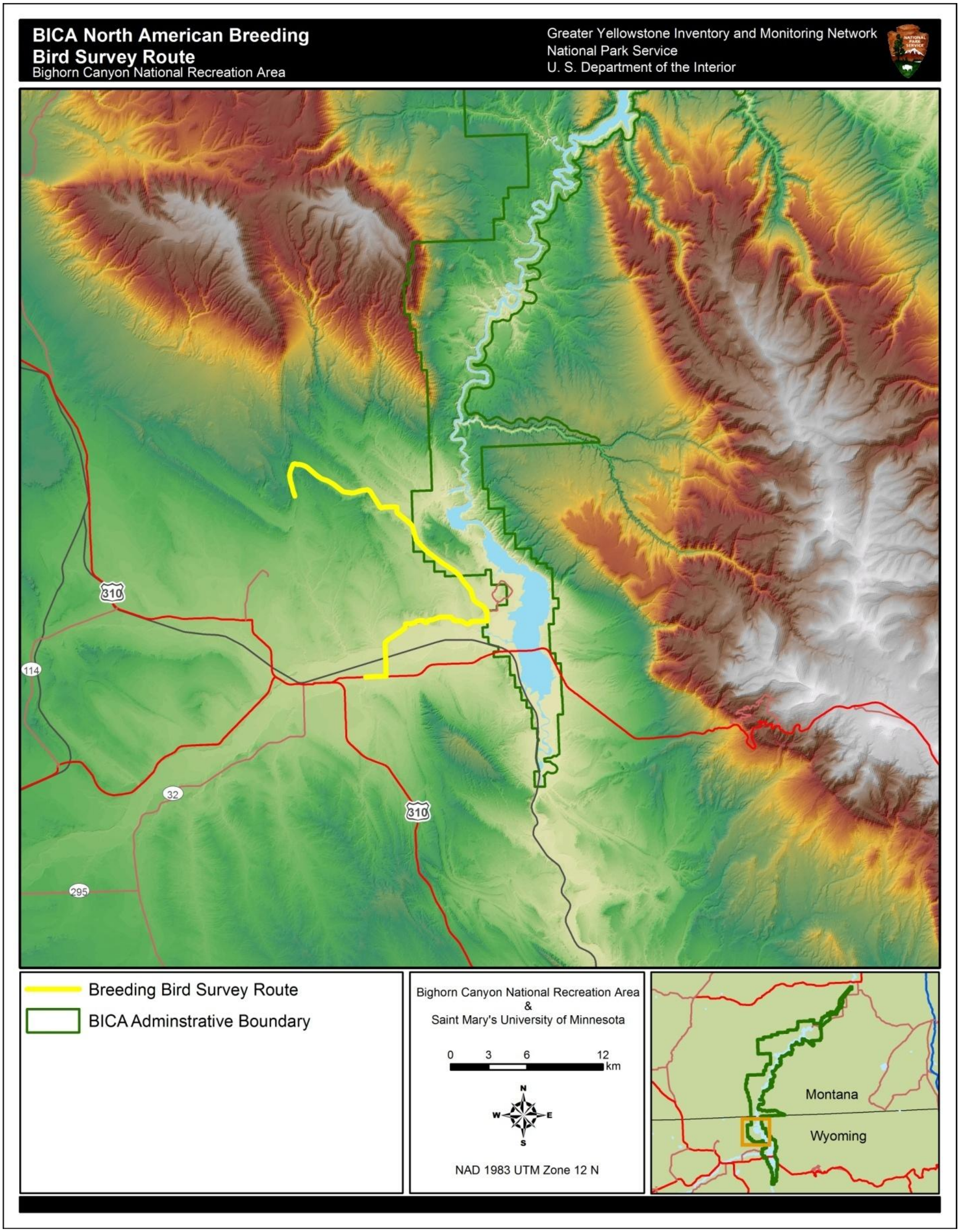

Plate 11. BICA Breeding Bird Survey Route 92037 (Lovell, WY).

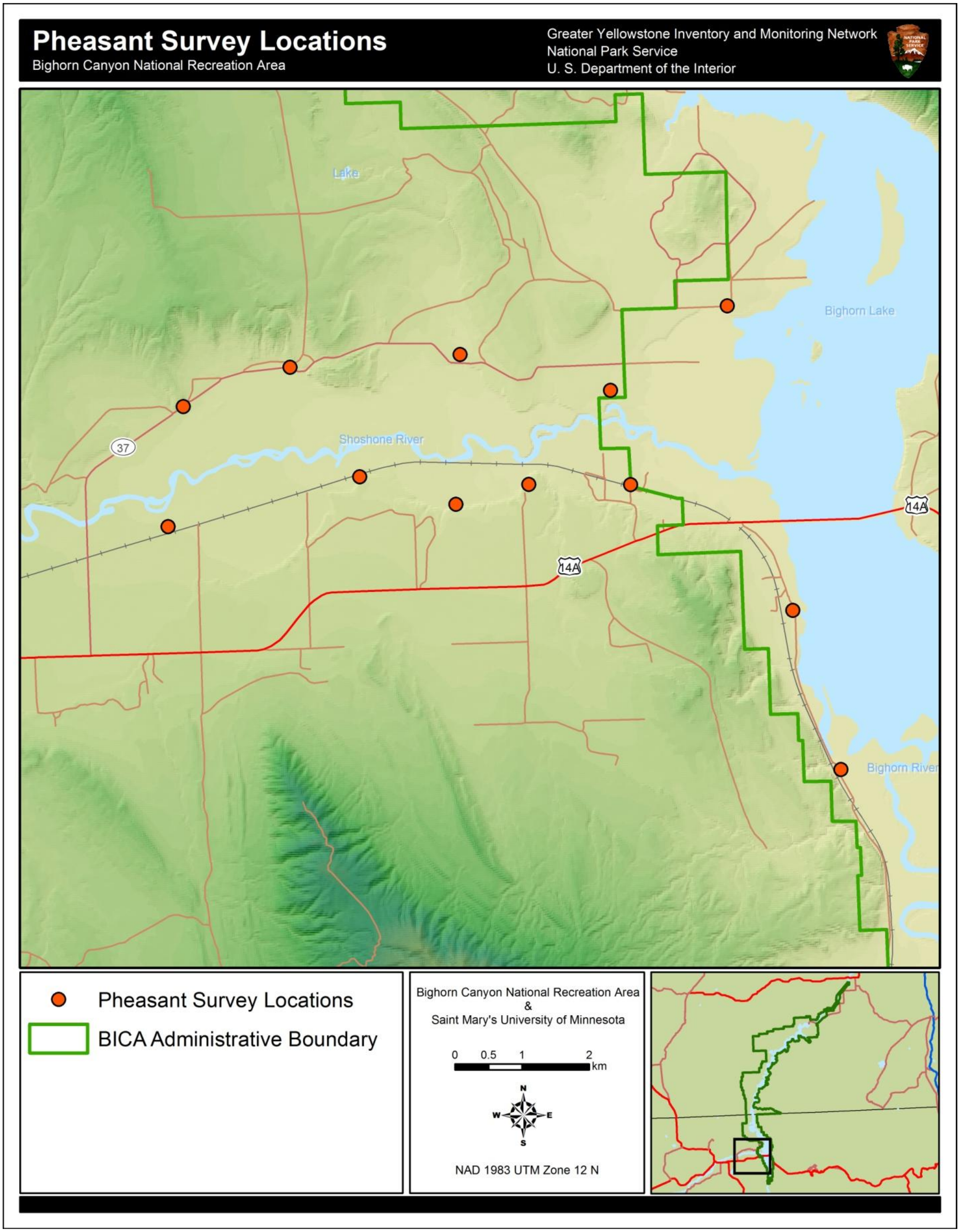

Plate 12. Pheasant crow count locations. Survey points include locations within BICA and within the Yellowtail Wildlife Habitat Management Area.

4.9 Land Birds

Description

Land birds are bird species that have a principally terrestrial life cycle (Rich et al. 2004). Bird populations often act as excellent indicators of an ecosystem's health (Morrison 1986, Hutto 1998, NABCI 2009). Birds are typically easy to observe and identify, and bird communities often reflect the abundance and distribution of other organisms with which they co-exist (Blakesley et al. 2010). BICA is home to a wide variety of habitats; the park has five climatic regions ranging from sub-alpine areas to high desert (NPS 2010). Monitoring avian population health and diversity in these habitats will be important for detecting ecosystem change.

Photo 13. Loggerhead shrike. Photo from AudubonAction.org.

Measures

- Population estimates for common breeding bird species
- Presence/absence of priority species
- Species richness

Reference Conditions/Values

The reference condition for BICA land birds is defined as the estimated densities per km^2, population sizes (Appendix C) (White et al. 2011). Because the number of detections may vary due to a number of factors (e.g., survey effort, weather), and because the BLM land and BICA have different areas, preference will be given to making comparisons between density (individuals per km^2) and occupancy (proportion of 1 km^2 units that are expected to be occupied) when comparisons are available.

BICA is home to several unique habitats, some of which (e.g., eroded landscape, juniper scrub) are infrequently found in other regions of Wyoming. The park also contains several areas that are critical bird areas (e.g., cottonwood riparian areas along the Bighorn and Shoshone Rivers); the Yellowtail Wildlife Management Area is identified by the National Audubon Society (NAS) as an important bird area of the U.S. (NAS 2012). BLM lands in the Wyoming portion of Bird Conservation Region (BCR) 10 (Northern Rockies) represent habitat types that may be most comparable to BICA, and land bird population trends for these lands may provide a suitable comparison for the park (Van Lanen, pers. comm., 2011).

Data and Methods

The NPS Certified Bird Species List (NPS 2011) (Appendix D) for BICA was used for this assessment. This list represents all of the confirmed bird species present in the park, and identifies species present in BICA. For this component, only bird species considered land birds (as defined by Rich et al. 2004) were included. SMUMN GSS removed game bird species from this list, as these species are discussed separately in Chapter 4.8 of this document. For the measure “population estimates for common breeding bird species”, the NPS Certified Species List was referred to in order to determine which species to evaluate. Species with the designations “Abundant” and “Common” were included in this measure’s discussion and analysis.

The BICA breeding bird survey route is part of the large-scale North American Breeding Bird Survey (BBS), which began in 1966 and is coordinated by the United States Geological Survey (USGS) and the Canadian Wildlife Service (Robbins et al. 1986). The standard BBS route is approximately 40 km (25 mi) long with survey points at every 0.8 km (0.5 mi). The survey begins ½ hour before sunrise, and at each survey point the number of birds seen and heard within a 0.4-km (0.25-mi) radius during a three-minute interval is recorded. Only BBS route 92037 (Lovell Route) crosses within the park boundaries (Plate 13). This route was surveyed annually from 1989-2007 (USGS 2011).

The Kane, WY, Christmas Bird Count is part of the International Christmas Bird Count (CBC), which started in 1900 and is coordinated internationally by the Audubon Society. The Kane, WY, CBC is near BICA (the count extends into BICA’s boundaries), and has been conducted annually since 1991. Multiple volunteers survey a 24-km (15-mi) diameter on one day, typically between 14 December and 5 January. The center point of the 24-km diameter is the historic town of Kane, WY (44-50'37" N, 108-12'10" W) (Plate 13).

Unlike the BBS, the CBC surveys overwintering and resident birds that are not territorial and singing; this often results in different survey results than the BBS. Because of this discrepancy, CBC data is not used in this assessment as the reference condition for this component includes only breeding birds; comparing the CBC list (which includes non-breeders and migrants) to a breeding bird list is not appropriate or accurate (Van Lanen, pers. comm., 2011).

The Rocky Mountain Bird Observatory (RMBO) and its partners monitor land bird populations in several BCRs across the North America; BICA lies within BCR 10 (Figure 14) and has been monitored by RMBO and its partners since 2010 (White et al. 2011). Land bird monitoring in BICA is part of the “Integrated Monitoring in Bird Conservation Regions (IMBCR)” program, and utilizes a spatially-balanced sampling design during survey efforts (White et al. 2011).

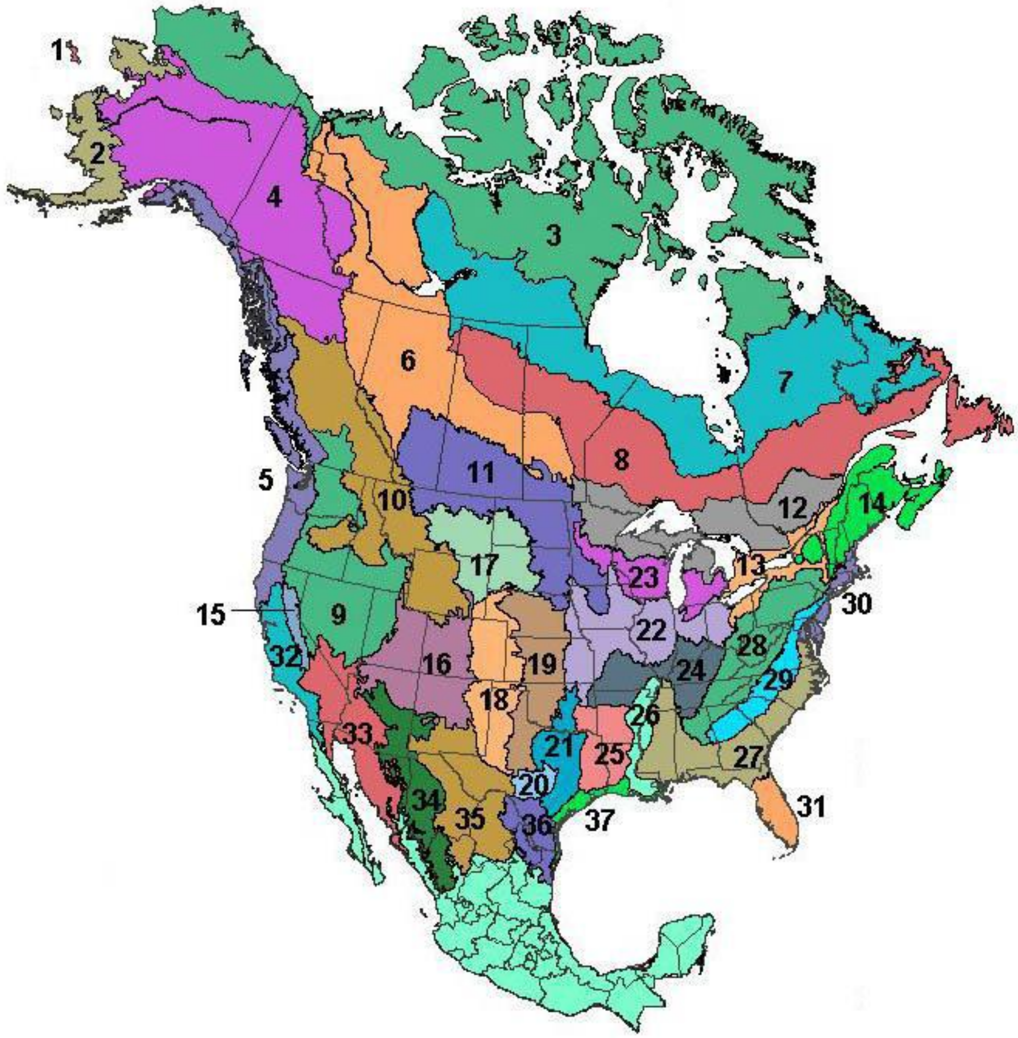

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Figure 14. Bird Conservation Regions through North America. BICA lies within BCR 10. Image reproduced from (http://www.nabci-us.org/map.html).

The IMBCR land bird monitoring program established a series of strata and super-strata (White et al. 2011). Within these strata, RMBO and its partners utilized generalized random-tessellation stratification (GRTS) to select sample units (Stevens and Olson 2004, White et al. 2011). According to White et al. (2011):

> The IMBCR design defined sampling units as 1-km^2 cells that were used to create a uniform grid over the entire BCR. Within each grid cell we established a 4 x 4 grid of 16 points spaced 250 m apart (Figure 15, Plate 14)

Selected transects (Plate 14) were sampled early in the breeding season after all migratory species had returned to their breeding areas. Care was taken to not survey too early in the season, as an early survey could potentially miss migratory breeding species or could sample transient birds that are migrating through the area (Hanni et al. 2011). Each point on a transect was sampled for six minutes using methods that allow for estimating detection probability through the principles of distance sampling (Buckland et al. 2001, Thomas et al. 2010), removal modeling (Farnsworth et al. 2002) and occupancy estimation (MacKenzie et al. 2002 , MacKenzie 2006). All bird species detected were recorded, along with several variables such as distance from the observer, habitat type, weather, and land ownership (Hanni et al. 2011).

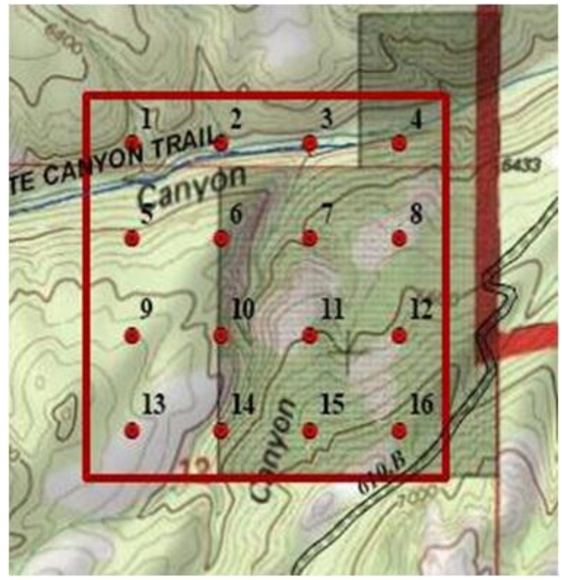


Figure 15. Example of a grid cell created by the RMBO using the IMBCR design. Reproduced from White et al. (2011).

The 56 IMBCR survey transects on BLM land in Wyoming serve as the reference condition for this assessment. The values included in were collected using the same RMBO methodology as described above.

Current Condition and Trend

<u>Population Estimates for Common Breeding Bird Species</u>

NPS Certified Bird Species List

The NPS Certified Bird Species List (NPS 2011) only identifies species confirmed within BICA boundaries and does not allow for population estimates for common breeding bird species. However, the NPS Certified Bird Species List does identify the species of breeding birds and common birds in the park (Appendix D).

Breeding Bird Survey

Techniques for counting land birds can be divided into two categories: index counts, and empirical modeling techniques that directly estimate species density (Rosenstock et al. 2002). An index count is a method that tallies the number of bird detections during surveys of points, transects, or other defined regions (Kendeigh 1944, Verner 1985, Bibby et al. 1992, Ralph et al. 1995, Rosenstock et al. 2002). Index counts quantify land bird species' distribution, occurrence, habitat relationships, and population trends (Rosenstock et al. 2002). Notable examples of long-term population index counts in BICA are the North American BBS and the CBC.

BBS route 92037 (Lovell, WY) was surveyed annually from 1989-2007 (USGS 2011). Only a portion of this route enters BICA land (Plate 15), so results from the survey may not be completely indicative of the land bird population in BICA. Counts such as the BBS are neither censuses nor density estimates, and results should only be viewed as indices of population size

(Link and Sauer 1998). Possible bias of roadside count locations limit the usefulness of BBS data and it is not advisable to estimate population sizes from these data (Link and Sauer 1999).

IMBCR Land Bird Sampling

Empirical modeling techniques that directly estimate species density typically use field procedures similar to index counts; however, these techniques have an analytical component involved that will model variation in species' detectability to yield robust density estimates (Rosenstock et al. 2002). An example of this modeling technique in BICA is the IMBCR program.

In BICA, RMBO has conducted spatially balanced sampling of land bird populations under the IMBCR program during the 2010 and 2011 breeding seasons. Data collected from these land bird surveys can be used to estimate densities of common breeding species in BICA. Unfortunately, due to small sample size the occupancy and density results may not be representative of the entire BICA area (some habitat types may not be represented by the two surveys conducted each year) and have a large degree of uncertainty (exhibited by large coefficients of variation) (Van Lanen, pers. comm., 2011). Given increased sampling intensity, density and occupancy estimates obtained from the IMBCR surveys can be used to assess not only the overall population size and proportion of area occupied by species, but also the overall quality of BICA bird habitat.

<u>Presence/Absence of Priority Species</u>

Many different agencies and lists define priority land bird species. This assessment focused on priority species from the following conservation lists:

- Montana Partners in Flight Level 1 Priority Bird Species (MT PIF 2000)
- The Wyoming Partners in Flight Level 1 Priority Bird Species (Nicholoff 2003)
- The Wyoming Natural Diversity Database (WYNDD) Species of Concern (Keinath et al. 2003)
- The U.S. Fish and Wildlife Service (USFWS) Birds of Conservation Concern 2008 (USFWS 2008)
- The Montana Natural Heritage Program (MTNHP) and Montana Fish, Wildlife and Parks (MT FWP) Animal Species of Concern (MTNHP and MTFWP 2009)
- Partners in Flight Species of Regional Importance for BCR 10 (Northern Rockies) (RMBO 2005)

NPS Certified Bird Species List

The NPS Certified Bird Species List includes 37 land bird species listed as priority species by one of the aforementioned lists (Appendix D).

Breeding Bird Survey

Eleven species, with representatives from five of the six priority species lists, were observed in BICA during Breeding Bird Surveys from 1989-2007 (Table 23). No birds listed on the Montana Partners in Flight Level 1 Priority Species List (MT PIF 2000) were observed.

Table 23. Priority land bird species observed in BICA on Breeding Bird Survey route 92037 (Lovell) from 1989-2007. Data retrieved from (https://www.pwrc.usgs.gov/BBS/PublicDataInterface/index.cfm).

Species	WY Level I [1]	WYNDD SC [2]	MTNHP & MT FWP 2009 [3]	USFWS 2008 [4]	PIF SRI [5]
northern harrier					x
short-eared owl	x	x			x
white-throated swift					x
loggerhead shrike		x	x	x	x
pinyon jay			x		x
Clark's nutcracker			x		x
sage thrasher			x	x	
Brewer's sparrow	x		x	x	x
sage sparrow	x	x	x	x	
lark bunting					x
lazuli bunting					x

[1] WY Level 1 = Wyoming Partners in Flight Level 1 Priority Species (Nicholoff 2003)

[2] WYNDD SC = Wyoming Natural Diversity Database Species of Concern (Keinath et al. 2003)

[3] MTNHP & MT FWP 2009 = Montana Animal Species of Concern (MTNHP & MT FWP 2009)

[4] USFWS 2008 = U.S. Fish and Wildlife Service Birds of Conservation Concern 2008 (USFWS 2008)

[5] PIF SRI = Partners in Flight Species of Regional Importance (http://www.rmbo.org)

Nine of the 17 priority species identified on the reference condition list for BICA land birds (Table 24) were observed during BICA BBSs. Six priority species from the reference condition were not observed in BICA, and two species (short-eared owl [*Asio flammeus*] and the pinyon jay [*Gymnorhinus cyanocephalus*]) were observed in BICA but were not listed in . The reference condition only represents BLM lands within Wyoming as comparable habitat to BICA, and may not be a truly representative list for the species and their density/distribution in the park.

IMBCR Land Bird Sampling

Six priority land bird species from five of the six priority species lists were observed in BICA during IMBCR land bird sampling from 2010-2011 (Table 24). No species listed on the Montana Partners in Flight Level 1 Priority Species List (MT PIF 2000) were observed.

Table 24. Priority land bird species observed in BICA during RMBO land bird sampling from 2010-2011. (RMBO 2011).

Species	WY Level I [1]	WYNDD SC [2]	MTNHP & MT FWP 2009 [3]	USFWS 2008 [4]	PIF SRI [5]
loggerhead shrike		x	x	x	x
grasshopper sparrow			x		
white-throated swift					x
sage thrasher			x	x	
lark bunting					x
Brewer's sparrow	x		x	x	x

[1] WY Level 1 = Wyoming Partners in Flight Level 1 Priority Species (Nicholoff 2003)

[2] WYNDD SC = Wyoming Natural Diversity Database Species of Concern (Keinath et al. 2003)
[3] MTNHP & MT FWP 2009 = Montana Animal Species of Concern (MTNHP & MT FWP 2009)

[4] USFWS 2008 = U.S. Fish and Wildlife Service Birds of Conservation Concern 2008 (USFWS 2008)

[5] PIF SRI = Partners in Flight Species of Regional Importance (http://www.rmbo.org)

Six of the 17 priority species identified on the reference condition list for BICA land birds (Table 24) were observed during BICA IMBCR surveys, while eleven priority species from the reference condition list were not observed. Nick VanLanen, RMBO biologist, noted that there is marginal habitat along the BICA IMBCR transects for species such as the sage (*Amphispiza belli*) and Brewer's sparrow (*Spizella breweri*) (Van Lanen, pers. comm., 2011). These species are dependent upon thick sage stands, and their occurrence in the park may be sporadic depending on the availability of this habitat.

Continued IMBCR monitoring with increased sampling intensity of the priority land bird species in BICA will allow for density and occupancy estimates to be compared to other areas of similar habitat within Wyoming or BCR 10. Due to limited available data at this time, the results from the IMBCR surveys are not appropriate for such a comparison.

Species Richness

NPS Certified Bird Species List
The species richness measure allows simultaneous assessment of abundance or presence for the entire land bird community. This measure can also indicate overall habitat suitability for land birds. The NPS Certified Bird Species List contains 159 land bird species. This list, however, does not allow for an analysis of species richness as no data are collected other than the presence of the listed species.

Breeding Bird Survey
Species counts for each year of the BBS were calculated (Figure 16). The average number of species observed on the BICA BBS from 1989-2007 was 36.8 species. There does not appear to be an increasing or decreasing trend in species richness observed each year (Figure 16). However, there may be undetected changes in species richness of native species compared to non-native species, or in Neotropical migrant species compared to resident species. Such changes would not be apparent in Figure 16. The BICA BBS only surveys a small portion of the park in Wyoming (Plate 15), and does not survey any of the park north of the Wyoming-Montana

border. Thus, species richness values shown here may not be truly indicative of the overall species richness for BICA.

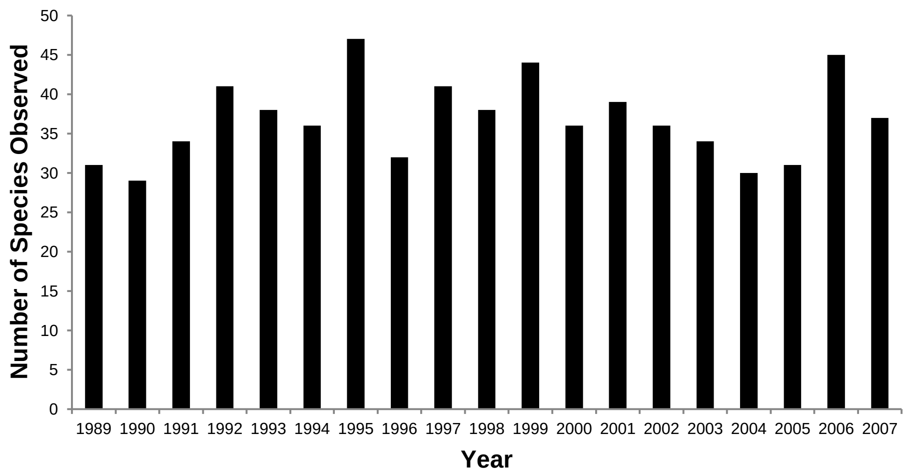


Figure 16. Number of land bird species detected during Breeding Bird Surveys in BICA from 1989-2007. Data retrieved from (https://www.pwrc.usgs.gov/BBS/PublicDataInterface/index.cfm).

IMBCR Land Bird Sampling

RMBO surveyed two transects under the IMBCR design during visits to BICA in 2010 and 2011(WY-BCR10-BH1 and WY-BCR10-BH3) (Plate 14). In 2010, 12 land bird species were observed on six points along transect WY-BCR10-BH1, while six species were observed on 16 points along transect WY-BCR10-BH3 (Figure 17). In 2011, 13 land bird species were identified on nine points along transect WY-BCR10-BH1, and nine species were identified on seven points along transect WY-BCR10-BH3 (Figure 17).

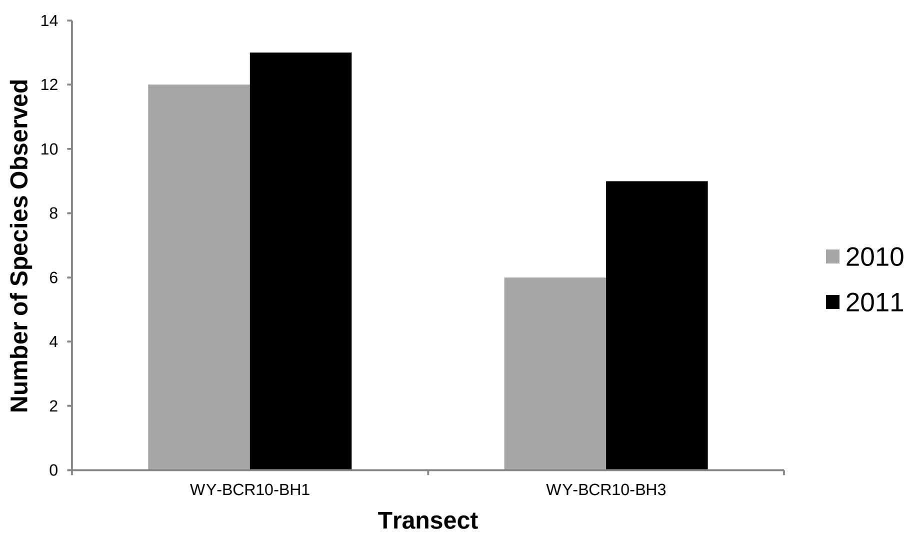


Figure 17. Number of land bird species detected during RMBO land bird monitoring from 2010-2011 (RMBO 2011).

The IMBCR transects within BICA have only been surveyed for two years, and deciphering any trends from these data is not possible at this time. Continued monitoring with increased sampling intensity will allow for long-term species richness trend comparisons and may provide insights into the habitat availability for land bird species in the park from year to year.

Threats and Stressor Factors

One of the major threats facing land bird populations across all habitat types is land cover change (Morrison 1986). Land cover change can be human-driven, but often times the encroachment of non-native plant species contributes. Land cover change is not restricted to the breeding habitat; many species depend on specific migratory and wintering habitat types. Altered habitats can compromise the reproductive success or wintering survival rates of species adapted to that habitat; they can also allow generalist, non-native species (such as the European starling [*Sturnus vulgaris*]) to move in and dominate a landscape. Priority species in BICA, such as the sage sparrow and Brewer's sparrow, often require specific vegetative communities (e.g., dense stands of sagebrush) for successful nesting to occur. A loss or alteration of these vegetative structures, or out-competition of resources by non-natives could compromise the nesting success of these species in BICA.

Another threat facing land bird populations is shifts in the reproductive phenology of birds. Several bird species depend on temperature ranges or weather cycles to cue their breeding. As global temperatures change, some bird species have adjusted by moving their home range north (Hitch and Leberg 2007). Other species have adjusted their migratory period and have begun returning to their breeding grounds earlier in the spring; American robins (*Turdus migratorius*) in the Colorado Rocky Mountains are now returning to their breeding grounds 14 days earlier compared to 1981 (NABCI 2009). A concern is that this shift in migration may be out of sync with food availability and could ultimately lead to lowered reproductive success.

The North American Bird Phenology Program (BPP) is currently analyzing the migration patterns and distribution of migratory bird species across North America (USGS 2008). Information from this analysis will provide new insights into how bird distribution, migration timing, and migratory flyways have changed since the later part of the 19th century. This information may also be applied to estimate changes in breeding initiation periods in specific habitats.

Data Needs/Gaps

Currently, data only exist for the southern portion of BICA. Land bird monitoring in the northern portion of the park (i.e., north of the Wyoming-Montana border) is needed to better gauge the true status of land birds in BICA. Completion of this monitoring would allow for a comparison of species richness and habitat availability in both regions of the park.

Breeding bird surveys and Christmas bird counts provide snapshots in time of species richness. However, only one survey/visit per year yields little information in terms of population trends. Further observation could help to remedy this data gap and could potentially help the park better understand the status of breeding bird species in the park as well. BBS route 92037 (Lovell) was surveyed annually from 1989-2007. Resuming this survey, despite its limited coverage of BICA, would be beneficial for future analysis.

Increased sampling (>2 samples per year) under the IMBCR spatially balanced land bird protocol would allow for density and occupancy estimates in the future. These estimates could provide baseline values that would serve as sources of comparison for future studies.

Overall Condition

Population Estimates for Common Breeding Bird Species
BICA staff assigned the measure of population estimates for common breeding bird species a *Significance Level* of 3. However, a *Condition Level* cannot be assigned for this measure at this time.

Direct estimations of population sizes using BBS data are impossible due to the potential bias of roadside locations. In addition, the BBS only surveys a small portion of the park and may not provide an accurate depiction of the common breeding bird population in the park. The CBC in the park has been a continuous survey effort since 1991, but this survey does not take place during the breeding season and does not present an accurate population estimate for the common breeding species in BICA.

The IMBCR land bird monitoring in BICA could provide reliable estimates of species density and occupancy, should sampling intensity be increased in the future. However, at this time the data are not sufficient to make estimates regarding population size.

Presence/Absence of Priority Species
Presence/absence of priority species in BICA was assigned a *Significance Level* of 2. The *Condition Level* for this component was not assigned due to a lack of long term data.

The NPS Certified Bird Species List includes 37 species that various sources recognize as priority species. This number is above what was expected for the reference condition of this component (Appendix C). However, the reference condition includes only breeding species while the NPS Certified Bird Species List includes all bird species (not just breeding). Thus, a comparison between the two lists is not appropriate.

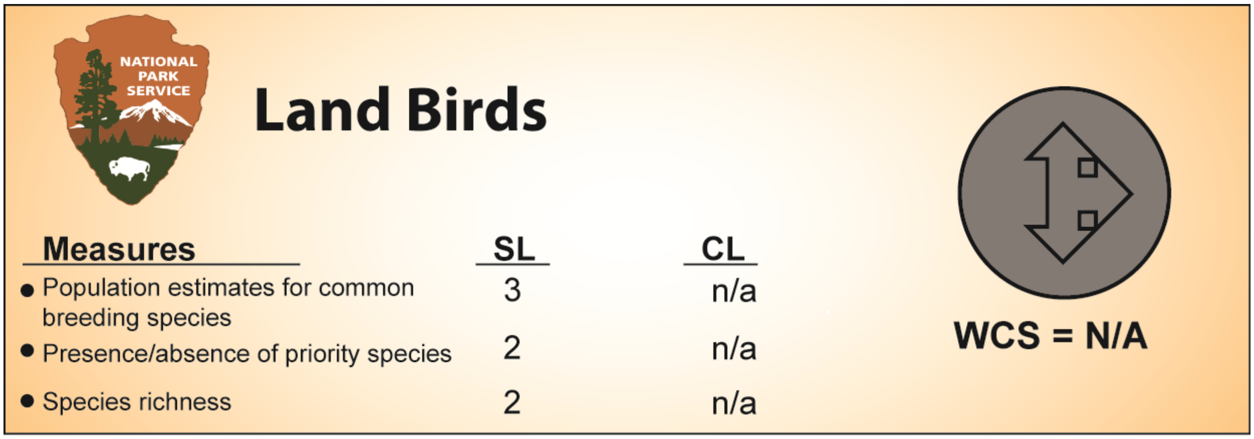
The BBS and the IMBCR surveys identified several priority species as being present in the park. Compared to the reference condition, the BBS identified nine of the 17 priority species expected; the BBS also identified two priority species not listed in the reference condition. The IMBCR survey efforts identified six of the 17 priority species in the park. However, this survey has only been conducted for two years.

While condition cannot be assessed at this time, there are no indications in the data available to SMUMN GSS that there are significant concerns at this time. Nonetheless, BICA is home to many priority species that may require future monitoring. The establishment of a winter/migratory reference condition for future analyses may provide more insight into the overall condition of the birds in BICA.

Species Richness
BICA staff identified the *Significance Level* for species richness as a 2. Because survey and count efforts have not studied all areas of the park it is not appropriate to assign a *Condition Level* at this time.

The IMBCR surveys and the BBS efforts give no indication of any increasing or decreasing trends in species richness. However, without sampling of all regions of the park (specifically the northern regions), an assessment of condition for this measure is not possible.

Weighted Condition Score
A Weighted Condition Score for Land Birds in BICA was not assigned because all of the measures had unknown *Condition Levels*.



Sources of Expertise
Chris White, Science Division, Rocky Mountain Bird Observatory
Nick Van Lanen, Science Division, Rocky Mountain Bird Observatory

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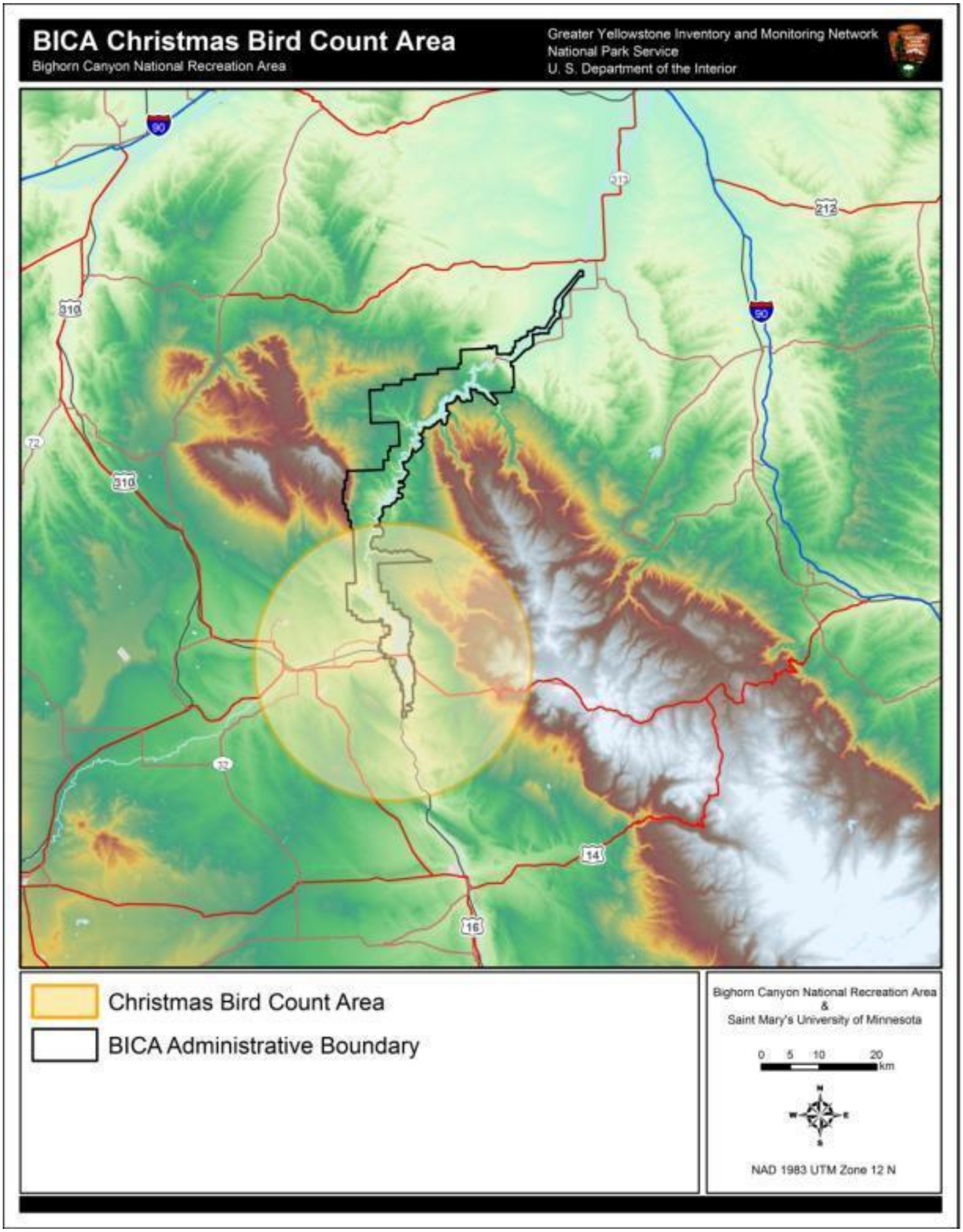

Plate 13. BICA Christmas Bird Count survey area.

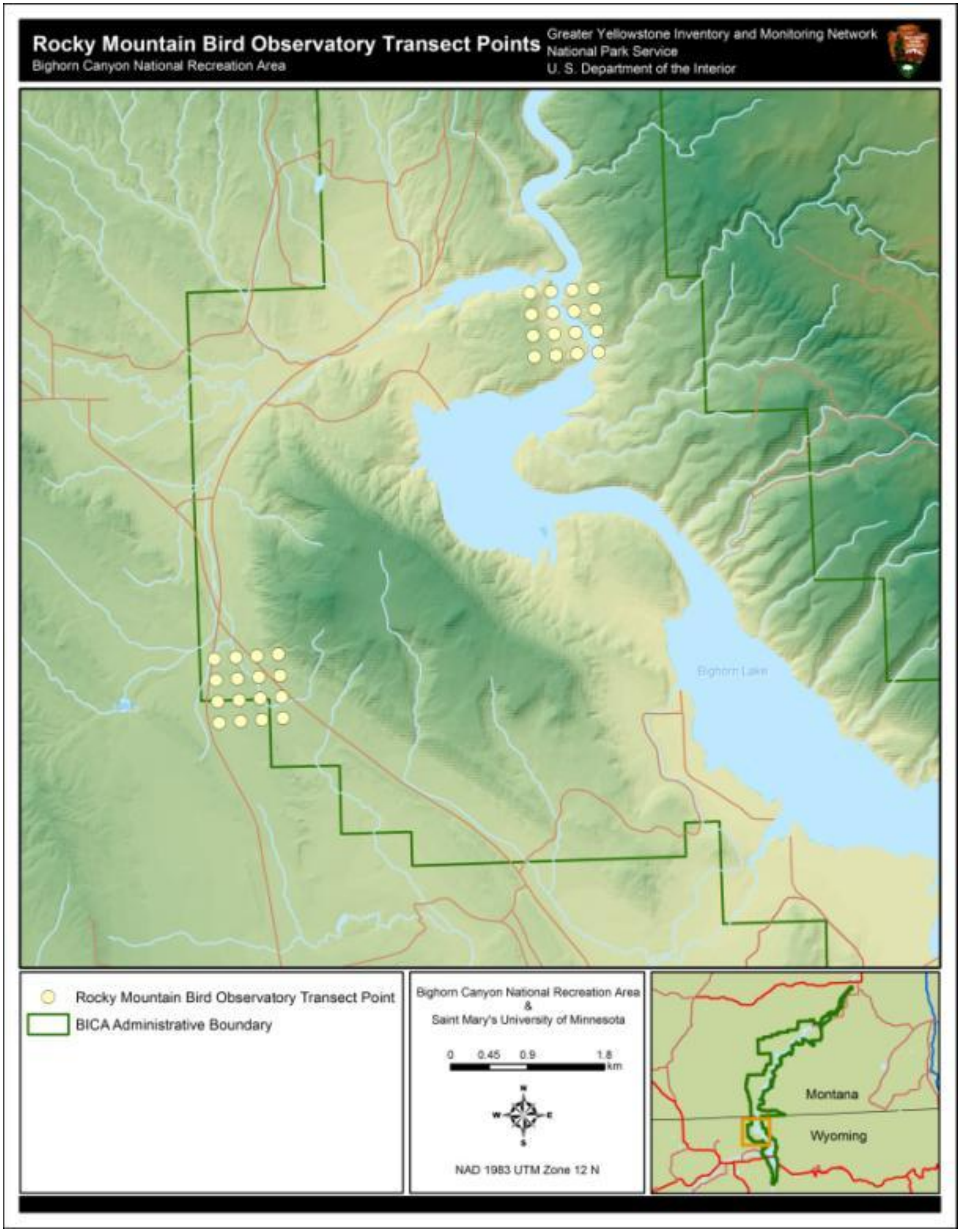

Plate 14. Rocky Mountain Bird Observatory sample units and transects surveyed in BICA from 2010-2011.

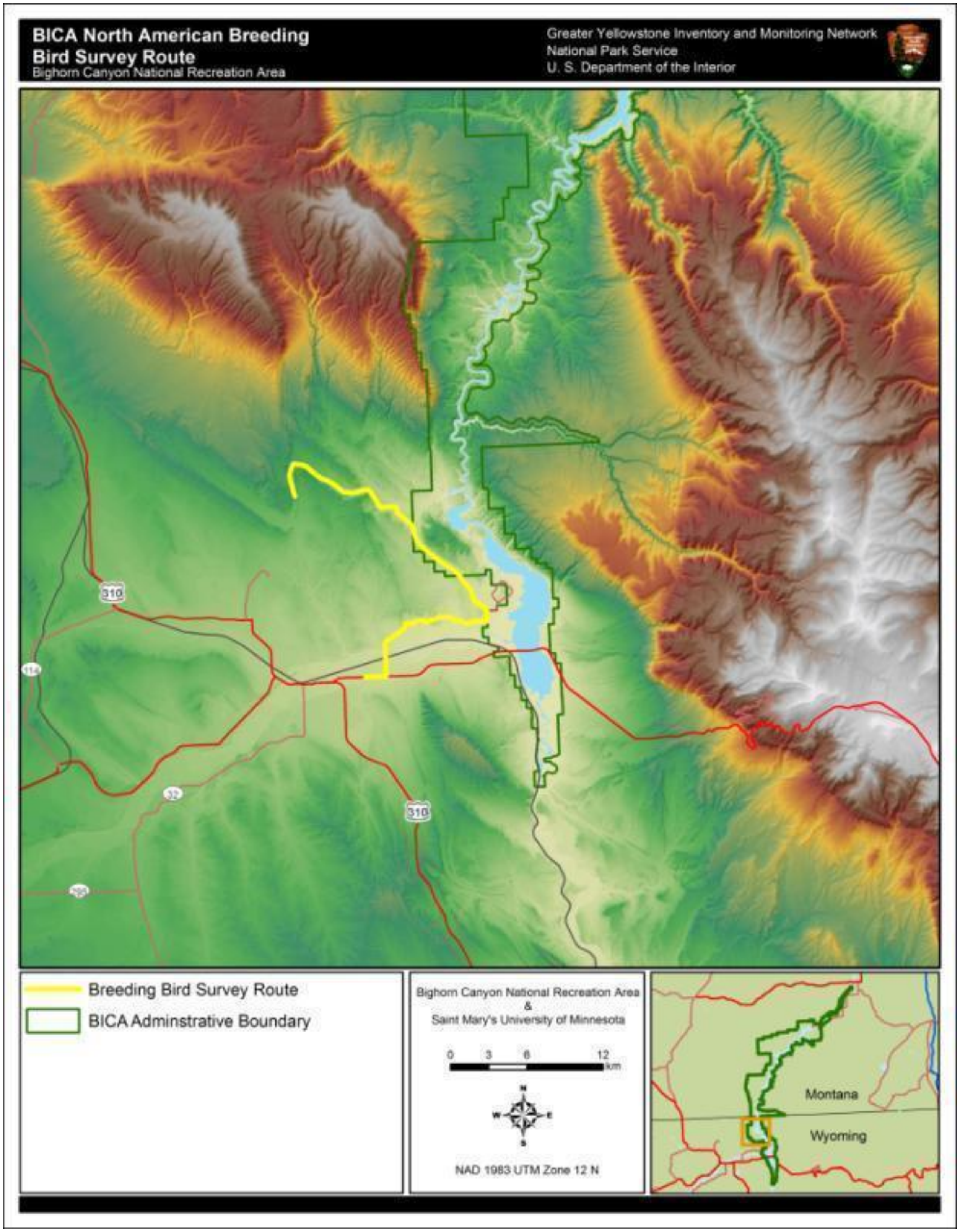

Plate 15. BICA Breeding Bird Survey Route 92037 (Lovell, WY).

4.10 Peregrine Falcon

Description

The North American peregrine falcon (*Falco peregrinus*) is a medium-sized raptor with a home range extending from Mexico to northern Canada and Alaska (Ambrose 1998). In the northern part of the species' range, the peregrine falcon is highly migratory. Birds will travel as far south as Brazil and Argentina for the winter months (Guldager et al. 2005). The peregrine's diet consists almost exclusively of avian species; it strikes its prey in mid-air with a clenched foot, stunning or killing it, and then turns to catch it in mid-air (Ehrlich et al. 1992).

There are three subspecies of peregrine falcons in North America: *F.p. tundrius*, a resident of the northern tundra of Alaska and Canada; *F.p. pealei*, which is found in the southern coastal regions of Alaska; and *F.p. anatum*, a resident of the forested interior of Alaska, Canada, and the continental U.S. (Ambrose et al. 1985). The *F.p. anatum* subspecies is the only subspecies to occur in the continental U.S. The subspecies' range includes most of the continental U.S. and Canada, and it is commonly referred to as the American peregrine falcon (del Hoyo et al. 1994).

The American peregrine falcon normally nests in a scrape on rocky cliff edges near water or open country, and occasionally will use the abandoned stick nests of other raptor species (McEneaney et al. 1998, The Peregrine Fund 2011). Cliff nests are generally located under an overhang, on ledges with vegetation, and with a south-facing orientation (Terres 1991). However, In Montana, no preference to orientation has been observed (Sumner, pers. comm., 2011). In the GRYE, peregrine nests have typically been located on the upper third of a large cliff face, at least 45.7 m (150 ft) off the ground (Greater Yellowstone Science Learning Center 2008). The American peregrine falcon's clutch size typically consists of three to four eggs (McEneaney et al. 1998, The Peregrine Fund 2011). Fledged falcons will reach sexual maturity around two years of age (USFWS 2003), although one-year-old birds will occasionally attempt to breed (White et al. 2008).

Photo 14. Adult peregrine falcon (USFWS photo).

American peregrine falcon populations experienced a well-documented population decline between the 1950s and late 1970s. The use of persistent organochlorine pesticides, particularly dichlorodiphenyltricholoroethane (DDT), had devastating effects on falcon populations. Because of DDT's lipophilic properties, it was able to rapidly bioaccummulate in ecosystems (especially in predatory birds). DDT magnified though the food chain, and more chemicals were concentrated within apex predators (such as the American peregrine falcon) than in other animals within the same environment (Connell et al. 1999). The most significant effect of the pesticide was that it caused the birds to lay thin-shelled eggs that often failed to hatch and, consequently, lowered the species' productivity (Ratcliffe 1993).

By the mid-1970s, peregrine populations were nearly eradicated from the eastern and midwestern U.S., and only a few hundred breeding pairs remained in the western U.S. (USFWS 2003). As a result, the American peregrine falcon was listed as a federally endangered species in 1970 under the Endangered Species Conservation Act of 1969, a precursor to the Endangered Species Act (ESA) of 1973 (USFWS 2003).

DDT was sprayed in and around BICA in the 1950s to combat spruce budworm (*Choristoneura* spp.) infestations (McEneaney et al. 1998). In 1972, the United States banned the use of DDT and other organochlorine pesticides (Flamme et al. 2007). Due in large part to this ban, but also due to large-scale captive breeding and reintroduction efforts, the American peregrine falcon population in the continental United States rebounded to over 2,000 breeding pairs in 2002 (White et al. 2002, as cited in USFWS 2003). Because of the range-wide recovery of the American peregrine falcon following the DDT ban and ESA listing, the species was removed from the USFWS List of Threatened and Endangered Species on 25 August 1999 (Mesta 1999, USFWS 2003).

In the late 1970s, surveys in the northwestern U.S. found no occupied American peregrine falcon nest sites in Idaho, Montana, or Wyoming (NPS 2010). In the GRYN, falcon reintroduction efforts were lead by The Peregrine Fund of Boise, ID. These efforts began with the release of 11 juvenile American peregrine falcons in the Jackson Hole, WY, area in 1980, and four juveniles in the Centennial Valley of Montana in 1981 (NPS 2010). By the late 1980s, almost 100 peregrines had been released in Grand Teton (GRTE) and Yellowstone (YELL) National Parks.

By 1994, 28 American peregrine falcons had been released in BICA (NPS 2010). BICA has nearly 112 km (70 mi) of steep canyon walls along Bighorn Lake that provide suitable peregrine nesting sites, and also provide perching and nesting sites for many prey species (e.g., rock dove [*Columba livia*]). The success of the reintroduction efforts in the area is evident; 30 years ago, the region was devoid of peregrines, and now 15 territories are present in and adjacent to BICA, and GRTE and YELL have established populations (NPS 2010).

Measures

- Nesting population size
- Productivity
- Annual percent occupancy

Reference Conditions/Values

The reference condition for peregrine falcons in BICA is a nesting population size of 3-4 pairs.

Data and Methods

Jay Sumner, Director of the Montana Peregrine Institute, has coordinated statewide surveys of American peregrine falcons in Montana since 1999 (Sumner and Rogers 1999, 2001, 2003, 2006; Rogers and Sumner 2000, 2002, 2004; Sumner and Shreading 2010). These surveys monitored the BICA area as part of the study area. According to Sumner and Shreading (2010), some specific objectives of these surveys included:

- Determining the status and trends of Montana’s peregrine falcon population

- Recording productivity at active peregrine falcon territories
- Recording activity and productivity at 15 Montana peregrine falcon territories selected by the USFWS for monitoring

In 2008, Shreading and Sumner (2008) conducted an extensive survey of the American peregrine falcon population in BICA. This survey was part of the same statewide survey conducted by the Montana Peregrine Institute, but efforts were much more intensive than in previous years. The study area consisted of a stretch of the Bighorn River between Horseshoe Bend and the Yellowtail Dam. The survey located and documented active American peregrine falcon territories in the park and adjacent areas.

Current Condition and Trend

<u>Nesting Population Size</u>
The nesting population size of American peregrine falcons in the GRYN was at, or very near, zero occupied territories in the late 1970s and early 1980s (Shreading and Sumner 2008, NPS 2010). Reintroduction of the American peregrine falcon to parks in the GRYN began in 1980, and reintroduction efforts were largely successful (GYSLC 2008, Shreading and Sumner 2008, NPS 2010). Since GRYN reintroductions began, 28 American peregrine falcons have been released into BICA (NPS 2010).

The Montana Peregrine Institute and several cooperating agencies have conducted annual American peregrine falcon surveys across the state of Montana since 1999 (Sumner and Rogers 2006). The intensity of the surveys has varied by area and by the number of volunteers available. In BICA, the intensity of the surveys has been limited. Surveys identified five separate eyries in BICA between 1994 and 2007 (Sumner and Rogers 2006, NPS 2010). During this same time, the average nesting population size was 2.14 nests. These initial surveys were not extensive in the BICA area (Shreading and Sumner 2008), thus the number of active territories in the park may have been significantly higher (or lower) than five.

During an intensive American peregrine falcon survey in 2008, Shreading and Sumner (2008, p. 2) defined active territories as “areas occupied by two adults attempting to nest.” The surveyed area of BICA had a population size of 11 territories in 2008 (Table 25), and only five of the 11 identified territories had been previously identified as active (Shreading and Sumner 2008).

Table 25. American peregrine falcon eyries surveyed and number of young fledged during Shreading and Sumner (2008) intensive surveys in BICA.

Eyrie Name	Date Visited	# of Young Fledged
Devil Canyon	6/19/2008	3
Pete's Canyon	7/1/2008	3
Dead Indian Hill	6/26/2008	4
Stateline	7/1/2008	0
Dryhead	7/8/2008	1
Black Tail Creek	7/9/2008	3
Crooked Creek*	7/14/2008	2
Cottonwood Creek*	7/14/2008	2
Frozen Leg	7/16/2008	3
Eye of the Eagle	7/23/2008	2
Black Canyon (BICA)	7/30/2008	0

* outside of BICA

Fifteen American peregrine falcon territories were active in 2009 (Sumner and Shreading 2010). The number of active nests in BICA from 1994-2009 is displayed in Figure 18. The population has increased from just one active territory in 1994, to 15 active territories in 2009. The initial surveys (1994-2007) were not extensive in the BICA area (Shreading and Sumner 2008), thus the number of active territories in the park may have been significantly higher (or lower) than what is reported in Figure 18.

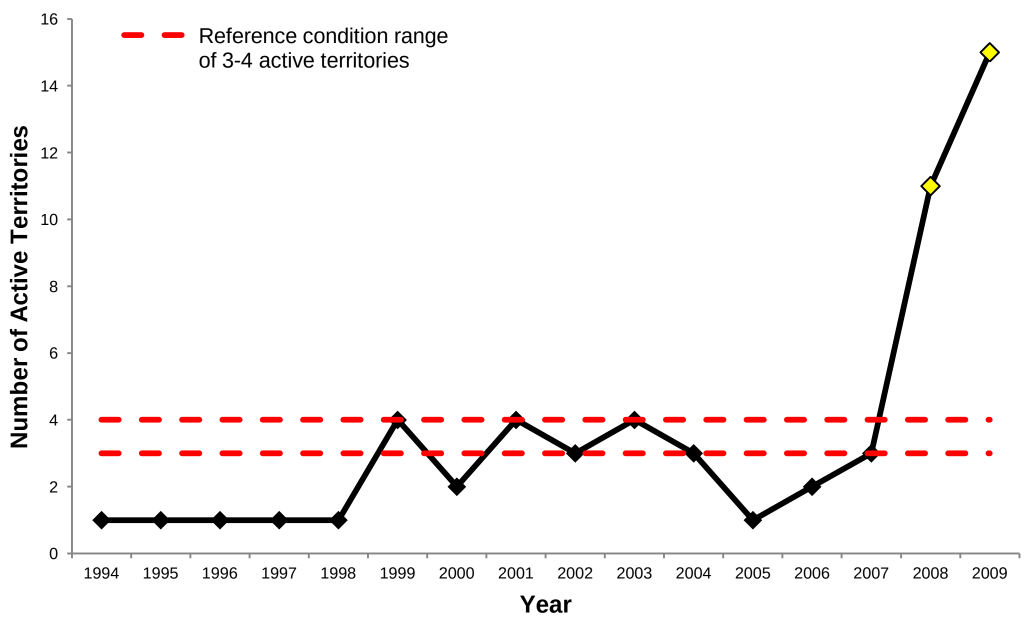

Figure 18. Number of active American peregrine falcon nesting territories in BICA from 1994-2009. Intensive survey results from 2008 and 2009 (Shreading and Sumner 2008, Sumner and Shreading 2010) are represented in yellow. All data prior to 1999 are based only on the Devil Canyon territory.

The BICA population was not surveyed in 2010, but will be surveyed in 2012 as part of the national peregrine falcon post-delisting monitoring program as mandated by the ESA (Sumner and Shreading 2010).

Compared to the reference condition of 3-4 active nesting territories, the BICA population is currently in good condition and improving. 2008 and 2009 surveys indicated a nesting population well over the reference condition (11 active territories in 2008, and 15 active territories in 2009), and a future survey in 2012 may provide more insight on the current trend of the American peregrine falcon population in BICA.

Productivity

Ambrose et al. (2008) defines productivity as the number of nestlings per total breeding pairs. Sumner and Rogers (2006) reported the annual productivity of American peregrine falcons in BICA from 1994-2007. Productivity ranged from 1.00 nestlings per breeding pair (1999) to 4.00 nestlings per breeding pair (1994) (Figure 19). All data prior to1999 are based only on the Devil Canyon territory and may not be comparable to other years (Sumner, pers. comm., 2011).

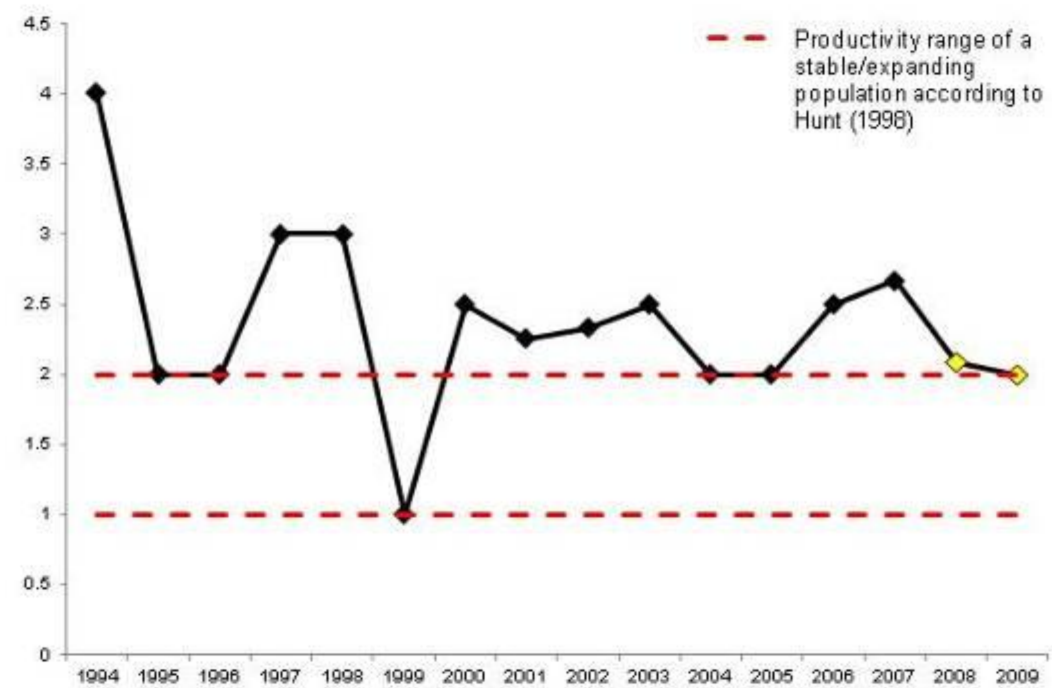

Figure 19. Annual productivity estimates for BICA American peregrine falcons. Intensive survey results from 2008 and 2009 (Shreading and Sumner 2008, Sumner and Shreading 2010) are represented in yellow. All data prior to 1999 are based only on the Devil Canyon territory.

Shreading and Sumner (2008) and Sumner and Shreading (2010) reported the results of intensive peregrine surveys during the 2008 and 2009 breeding seasons. Productivity for BICA in 2008 was 2.09 nestlings per total breeding pairs, while productivity for BICA in 2009 was 2.00 young per territory (Figure 19). Shreading and Sumner (2008) did not survey all of BICA, as only a reach of the Bighorn River from Horseshoe Bend to Yellowtail Dam was surveyed. Furthermore, two of the territories identified (Crooked Creek and Cottonwood Creek) lie outside of BICA's boundaries. Thus, the productivity estimates from Shreading and Sumner (2008) may not be representative of American peregrine falcon occupancy in other reaches of the park.

Hunt (1998) modeled the population dynamics of peregrines in the continental United States under various rates of adult mortality and juvenile survival and found that peregrine populations were at least stable when productivity was 1.00 to 2.00 young per pair, adult mortality was <15%, and juvenile mortality was <70%. These productivity estimates are consistent with estimates in expanding or stable populations in the United States (Corser et al. 1999, Mesta 1999, Hayes and Buchanan 2002, USFWS 2003). Since the peregrine falcon was delisted in 1999, the USFWS has enacted a policy that initiates a special review for populations falling below 1.00 young per pair (USFWS 2003).

Productivity results from the intensive 2008 and 2009 surveys were very similar. In 2008, 11 active territories produced 23 young (Table 25); the average number of young per territory was 2.09. In 2009, 15 active territories produced 30 young; the average number of young per territory was 2.00 (Figure 19). When compared to the Hunt (1998) thresholds, survey results from 2008 and 2009 provided productivity values consistent with an expanding or stable population (Figure 19). Productivity estimates from 1994-2007 were also consistent with an expanding population (1999 is the only year to have a productivity estimate <2.00). However, the surveys during those years were less intensive than in 2008 and 2009 and the results may not be as accurate.

Annual Percent Occupancy

Peregrine populations experienced drastic reductions in rates of territory occupancy and nest success in the 1950s and 1960s. In some regions of the continental U.S., rates of territory occupancy and nest success were at or near zero (USFWS 2003); it is believed that no peregrines fledged in the northeast U.S. in 1962 (Hickey and Anderson 1969). In Canada and Alaska, territory occupancy was 50% or less in the 1970s (Enderson et al. 1995, USFWS 2003).

Photo 15. Eye of the Eagle eyrie cliff. (Photo from Rogers and Sumner 2002).

BICA has only recently begun intensive survey efforts for American peregrine falcon nesting territories, and because of this, not all territories have been identified. This, combined with only a few years of nesting success data, makes determining annual percent occupancy impractical at this time.

Threats and Stressor Factors

Jay Sumner (pers. comm., 2011) indicates that the BICA peregrine population is largely free from major threats and stressors. One potential threat that may be affecting the species is West

Nile Virus (WNV). In North America, WNV has been associated with death in over 33 species of raptors (Nemeth et al. 2007), and American peregrine falcons may be a susceptible species (USFWS 2011), although definitive data are not available to support this.

Most raptor species become infected with WNV from mosquito bites, although there is also evidence that infections may occur when infected prey items are consumed (Garmendia et al. 2000, Komar et al. 2003, Nemeth et al. 2006a, 2006b, e2007). Monitoring of American peregrine falcon population size and available carcasses will be necessary to detect potential effects of WNV in BICA.

Data Needs/Gaps

An annual intensive survey of BICA, including nearby drainages and stretches of large cliff faces (e.g., Devil Canyon, Black Canyon, Big Bull Elk Creek) could potentially reveal new American peregrine falcon nesting territories. Observations made early in the nesting season (Shreading and Sumner [2008] visited from late-June to July) would provide a greater understanding of nesting success and failure for BICA.

Overall Condition

BICA staff assigned each of the measures (nesting population size, productivity, annual percent occupancy) a *Significance Level* of 3.

Nesting Population Size

BICA's American peregrine falcon nesting population size measure was assigned a *Condition Level* of 1. From 1999-2004, the number of active territories in the park fluctuated between three and four (which are within the reference condition range). 2005-2006 showed a drop in productivity, but this may be due to limited surveys in the park and because several of the nesting territories were not checked for occupancy (Sumner and Rogers 2006). Intensive surveys in 2008 and 2009 identified 11 and 15 territories, respectively, and indicated that the population had expanded greatly and was significantly higher than the reference condition of 3-4 pairs.

Productivity

The productivity measure for American peregrine falcons in BICA was assigned a *Condition Level* of 0. While the reference condition for this component does not directly relate to productivity, mean productivity estimates for BICA have consistently been within or above the Hunt (1998) range (1.00-2.00 nestlings/breeding pair) for a stable or expanding population. Furthermore, BICA American peregrine falcon productivity has been higher than the productivity reported for the entire Rocky Mountain/Great Plains Region (1.49 nestlings/breeding pair; Green et al. 2006), the state of Montana (1.70 nestlings/breeding pair; Sumner and Shreading 2010), and all regions in the United States (1.64 nestlings/breeding pair; Green et al. 2006).

Annual Percent Occupancy

SMUMN GSS could not assign this measure a *Condition Level* due to the lack of long-term data. Intensive American peregrine falcon surveys only recently began in BICA (2008) and it is possible that not all peregrine falcon nesting territories have been identified.

Weighted Condition Score
The Weighted Condition Score (WCS) (see Chapter 3 for methodology) for American peregrine falcons in BICA was 0.167. A WCS of 0.167 represents an overall condition of low concern (0.00 – 0.333).

Peregrine Falcons

Measures	SL	CL
• Nesting population size	3	1
• Productivity	3	0
• Annual percent occupancy	3	n/a

WCS = 0.167

Sources of Expertise
Jay Sumner, Director of the Montana Peregrine Institute

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4.11 Bighorn Lake Species

Description

Closure of Yellowtail Dam and the subsequent filling of Bighorn Lake transformed the Bighorn River into a diverse fishery. Along the length of the lake, the composition of the fishery changes according to the variation in many parameters, including depth, sediment load, flow, and temperature (Ruggles, pers. comm., 2012; Smith, pers. comm., 2012). Bighorn Lake's diverse fishery draws many anglers; it is one of the most fished lakes in the State of Montana. Each year, anglers spend about 15,000 hours on the lake (MTFWP 2011a) and pressure varies with season, surface water elevation, and sedimentation (Smith, pers. comm., 2012).

Measures

- Angling pressure/harvest
- Aquatic invasive species presence/absence and current abundance
- Species composition and abundance
- Mercury
- Sedimentation
- Turbidity

Reference Conditions/Values

Both MTFWP and WG&F actively work to mitigate and prevent all aquatic invasive species from establishing in the lake. Therefore, the reference condition for the aquatic invasive species measure is the absence of those species. Similarly, mercury is detrimental to the fishery and therefore the goal/reference condition for the mercury measure is minimum levels within the lake.

An explicit reference condition for species composition and abundance is not determined. To date, with the exception of a few sport fish, data describing populations of species since the formation of Bighorn Lake are unavailable.

Sedimentation reference condition derives from the original sediment-load projections developed during reservoir planning (see Section 4.17 of this document for a detailed discussion of sedimentation).

Reference conditions for turbidity and angling pressure/harvest are unknown.

Data and Methods

Multiple sources provided data and information for this assessment. GRYN provided many literature sources at the inception of the assessment. Fisheries biologists from MTFWP and WG&F provided additional data, literature, interpretation, and personal knowledge.

Current Condition and Trend

Aquatic Invasive Species Presence/Absence and Current Abundance

The management focus of the fishery at Bighorn Lake includes both native and non-native species (WG&F 2007). Many non-native fish species are present in Big Horn Lake Reservoir (Table 26). Some of the non-native species, such as common carp (*Cyprinius carpio*), were not intended to occur in Big Horn Lake, but WG&F does not consider any of the non-native species to be invasive (Smith, pers. comm., 2012).

Table 26. Native and non-native species in Bighorn Lake and their relative abundance (WG&F 2007).

Common Name	Scientific Name	Relative Abundance
Native Species		
burbot	*Lota lota*	rare
channel catfish	*Ictaurus punctatus*	abundant
flathead chub	*Platygobio gracilis*	common
western silvery and plains minnows	*Hybognathus* spp.	rare
longnose sucker	*Catostomus catostomus*	rare
shorthead redhorse	*Moxostoma macrolepidotum*	common
river carpsucker	*Carpiodes carpio*	abundant
sauger	*Sander canadensis*	abundant
shovelnose sturgeon	*Scaphirhynchus platorynchus*	rare
stonecat	*Notorus flavus*	abundant
white sucker	*Catostomus commersonii*	abundant
Non-native Species		
black bullhead	*Ameiurus melas*	rare
black crappie	*Pomoxis nigromaculatus*	common
bluegill	*Lepomis macrochirus*	rare
brown trout	*Salmo trutta*	rare
carp	*Cyprinus carpio*	abundant
emerald shiner	*Notropis aterinoides*	common
green sunfish	*Lepomis cyanellus*	rare
largemouth bass	*Micropterus samoides*	rare
rainbow trout	*Oncorhynchus mykiss*	rare
smallmouth bass	*Micropterus dolomieu*	common
spottail shiner	*Notropis hudsonius*	rare
walleye	*Sander vitreus*	common
white crappie	*Pomoxis annularis*	common
yellow perch	*Perca flavescens*	rare

Many non-fish invasive species that are present in waters throughout the west are a concern to management. Although not present in Bighorn Lake, zebra and quagga mussels (*Dreissena polymorpha* and *D. bugensis*) are two non-native species that are particularly invasive. These species filter feed and can remove large amounts of plankton and particulates from infested water bodies; this results in clearer water and altered food webs (USGS 2011). Other invasive species that exist in the western United States, such as New Zealand mud snails (*Potamopyrgus antipodarum*) and *Myxobolus cerebralis* (whirling disease parasite), are not present in Bighorn Lake.

Species Composition and Abundance

The fish community in Bighorn Lake is diverse and variable depending on the section of the reservoir. The higher reaches of Bighorn Lake are more silt-laden and consequently, support more turbid tolerant fishes. Closer to Yellowtail Dam, the lake is clearer and deeper, supporting more cool-water fishes (Ruggles, pers. comm. 2012; Smith, pers. comm. 2012). Table 26 provides a list of species known to occur in Bighorn Lake and their relative abundance (WG&F 2007). Data that explain specific trends in abundance over time are not available.

Recently, MTFWP and WG&F began a collaborative effort to augment the sauger population in Bighorn Lake (MTFWP 2011b). Sauger are native to the Bighorn River, although the creation of the lake developed additional non-native habitat. Natural spawning upstream of Bighorn Lake supported the sauger population in the lake for many years, while both MTFWP and WG&F focused management efforts on sustaining a walleye population through stocking sterile, triploid walleyes. Focusing stocking efforts on sauger and reducing walleye stocking will reduce the threat of hybridization between sauger and walleye and could create another premier fishery that draws more recreational visitors to Bighorn Lake (MTFWP 2011b).

MTFWP and WG&F performed the only formal creel survey at Bighorn Lake in 1992 (Yekel and Frazer 1992). The 1992 creel survey revealed that open-water angling pressure was higher than ice angling pressure and most anglers indicated that walleye was the preferred game species. In 1992, anglers caught walleye and brown trout in the highest proportions of all game fish, but catch per unit effort was still low (Yekel and Frazer 1992). Yekel and Frazer (1992) found a difference in primary species caught between the Wyoming and Montana portions of the reservoir. In the Wyoming portion, sauger was the primary species caught, then walleye and channel catfish. For Montana, walleye was the primary species, followed by yellow perch and black crappie.

Sedimentation

When the BOR planned the development of the Yellowtail Dam and Bighorn Lake in 1962, they projected that sediment would accumulate at a rate of 3,150 acre-feet per year. Total accumulation of sediment during the first 16 years was higher than anticipated, with sediment accumulating at a rate of 3,221 acre-feet per year (Blanton 1986). However, an examination of sediment loading from 1982 to 2007 yielded an average annual deposition rate of 1,986 acre-feet per year (Ferrari 2010). In 2007, total sediment accumulated in Bighorn Lake since its creation was 103,415 acre-feet, less than the projected 126,000 acre-feet. Section 4.17 of this document provides a more detailed discussion of sedimentation in the reservoir and the effects on visitor experience.

Data or literature describing the anticipated change in the fishery as the lake continues to fill does not exist. As the reservoir continues to fill, monitoring the changes in fish species composition and adjusting management to account for this will be crucial in maintaining a successful fishery.

Turbidity
The turbidity of the reservoir, especially in shallow water areas (<2m deep) during the growing season (April to October) is a factor that is limiting fishery productivity. Unfortunately, the vast majority of the shallow water in the reservoir exists near the inlets.

Threats and Stressor Factors
Aquatic invasive species will continue to be a threat to species in Bighorn Lake and all water bodies that experience human use. Monitoring and inspection of conveyances prior to launch (when possible) for these species should continue into the future and, if detected, appropriate actions are necessary for mitigation or removal.

Data Needs/Gaps
Mike Ruggles (pers. comm., 2012) stated that another creel survey would be beneficial, but the logistics and cost of a survey make it difficult to complete. Additionally, data on the use/importance of habitats most affected by reservoir operation (shallow water in particular) for key fish species is needed (Smith, pers. comm., 2012).

Overall Condition

Angling Pressure and Harvest
The *Significance Level* of the angling pressure and harvest measure is 1. MTFWP regularly collects and publishes pressure data based on mail-in surveys. Bighorn Lake is consistently one of the most fished lakes in Montana (MTFWP 2011a). Little is known about harvest rates in the reservoir. Mike Ruggles (pers. comm., 2012) indicated that walleyes and saugers are commonly pursued game fish, and Yekel et al. (1992) supports that claim. However, recent quantitative data do not exist. Therefore, *Condition Level* for this measure is unknown.

Aquatic Invasive Species Presence/Absence and Current Abundance
The project team defined the *Significance Level* of this measure as a 2. Currently, aquatic invasive species effects on the reservoir are minimal. Many of the invasive species present in other water bodies in the region are not present in Bighorn Lake. Continued monitoring for these species is important though and given the widespread influence of aquatic invasives in the region, there is still some concern. Therefore, the *Condition Level* for this measure is a 1, or low concern.

Species Composition and Abundance
The *Significance Level* of this measure is 3. Overall, collecting and updating species composition and abundance data is a costly process (Ruggles, pers. comm., 2012). Management of the fishery by both state resource agencies is collaborative and takes into account public demands, as with the sauger augmentation program. However, given the lack of quantitative data, *Condition Level* cannot be determined at this time.

Mercury

The project team defined the *Significance Level* of the mercury measure as 1. Data regarding mercury are limited, but the Montana Department of Public Health and Human Services (MDPHHS 2002) found the mercury levels of walleyes in Bighorn Lake Reservoir were high. In the 2002 survey, walleyes from 24.8-38.3 cm (9.8-15.1 in), 48.7-52.6 cm (19.2-20.7 in), and 68.6-69.9 cm (27.0-27.5 in) exhibited mean mercury concentrations of 0.20, 0.58, and 1.40 µg/g, respectively. Mercury levels exceeding 0.10 µg/g warrant concern for fish consumption; fish with greater than 0.66 µg/g should not be consumed by women of child-bearing age, children younger than 6 years of age, and nursing mothers (MDPHHS 2012). Given the high mercury in Bighorn Lake Reservoir, the *Condition Level* at this time is a 3, of significant concern.

Sedimentation
The *Significance Level* of this measure is 2. As of 2007, total sediment deposition was less than anticipated during reservoir development. However, data or literature that describes the change in the fishery as sedimentation continues does not exist. Therefore, *Condition Level* is currently unknown.

Turbidity
The *Significance Level* of this measure is 2. Data regarding the effects of turbidity on the fishery in the reservoir do not exist. Due to the lack of data, *Condition Level* is unknown.

Weighted Condition Score
Because four of the measures in this component have unknown *Condition Level*, *Weighted Condition Score* for this component is unknown.

Bighorn Lake Species

Measures	SL	CL
Angling pressure and harvest	1	n/a
AIS presence/absence and current abundance	2	1
Species composition and abundance	3	n/a
Mercury	1	3
Sedimentation	2	n/a
Turbidity	3	n/a

WCS = N/A

Sources of Expertise
Mike Ruggles, Fisheries Biologist, Montana Fish, Wildlife, and Parks
Mark Smith, Fisheries Biologist, Wyoming Game and Fish Department

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4.12 Tailwater Trout Fishery[1]

Description

When the Yellowtail and Yellowtail Afterbay Dams closed in October of 1965, the once warm and silty Bighorn River transformed into a coldwater fishery (MTFWP n.d.). The MTFWP stocked 293,000 rainbow trout (*Oncorhynchus mykiss*) in the river from May of 1966 until October 1985 with stocking occurring in all but 2 years during that period. Since stocking ceased, natural reproduction by rainbow and brown (*Salmo trutta*) trout has kept the excellent fishery intact (Ruggles, pers. comm., 2011).

Photo 16. Rainbow trout (NPS photo).

NPS owns roughly 3 miles (4.8 km) below the Yellowtail Dam. In 2010, MTFWP estimated that the Bighorn River fishery produced $52 million in revenue for the state of Montana. The 13.2-mile (21.2-km) stretch of river below Yellowtail Dam is consistently one of the most fished destinations in the state of Montana. In 2009, individuals spent 109,278 ± 5,408 angling days on this stretch of river, the third highest for any body of water in the state.

Measures

- Flow
- Trout per river mile
- Reproduction
- Angling days
- Mercury

Reference Conditions/Values

<u>Flow</u>

The reference condition for flow in the tailwater is complicated. MTFWP prefers a minimum flow under normal conditions of 2,500 CFS. However, this is not an optimum fishery flow. A maintained flow of at least 3,500 CFS would be optimum for the tailwater fishery, but this is rarely achievable. As flows decrease below 2,500 CFS, side channel habitat is lost at an increasing rate. However, drought conditions make maintenance of a 2,500 CFS flow unrealistic. Therefore, a flow of 1,500 CFS is recognized as the absolute minimum flow during extreme drought conditions because it is a balance point for maintenance of the fishery and reservoir levels.

[1]U.S. standard format is the primary unit of measurement in this section of the document.

Trout per River Mile

The reference condition for trout per river mile is 3,000-5,000 trout over 10 inches (25.4 cm) per river mile; this is the normal expected value for the tailwater. If numbers remain in this range, concern regarding this measure is minimal. Historically, population estimates for trout over 10 inches have exceeded 8,000 trout per mile (4,970 per km) with lows approaching 400 trout per mile (250 per km) (Ruggles, pers. comm., 2011; Frazer 1993, 1998, and 2003).

Angling Days

There is no specific reference condition for angling days at BICA. Provided the fishery is performing well (regarding trout per river mile and reproduction), angling days should remain stable or increase.

Reproduction

A specific numeric reference condition for reproduction does not exist. Mike Ruggles (pers. comm., 2011) indicated that trout per river mile numbers and the associated age and length classes reflect reproductive success. However, there are threats to rainbow trout reproduction that are associated with river geomorphology; these are discussed in the reproduction section later in the document.

Mercury

Reference condition for mercury concentrations at BICA is incomplete. While state and federal agencies provide guidance on consumption of fish, data regarding mercury concentrations of fish in the tailwater are not available. Therefore, current condition as indicated by this measure is unknown.

Data and Methods

The primary source of information used to construct this document was the MTFWP Montana Fisheries Information System, commonly referred to as the MFISH database (MTFWP 2011). The Montana Strategic Planning and Data Services Bureau of the Fish and Wildlife Division of MTFWP manages the database. This database contains information regarding “fish species distribution, supporting data for distribution, and information related to the management of aquatic resources in Montana” (MTFWP 2011, p. 2). MTFWP uses data provided by MTFWP, USFS, USFWS, BLM, and tribal fisheries biologists to update the MFISH database on a yearly basis.

SMUMN GSS processed the data from the MFISH database using Microsoft Excel to produce graphs and tables for this document. Catch per Unit Effort (CPUE) data were derived from MFISH fishing log data.

The flow data used in this assessment come from USGS Gage 06287000, near St. Xavier, MT. The parameter extracted from the gage to determine condition of the flow measure was mean monthly flow (CFS).

Current Condition and Trend

Flow

From January 2000 to September 2010 (129 months), mean monthly flow of the Bighorn River near St. Xavier, MT fell below the established reference condition of 1,500 CFS on 22 occasions.

All of the months that did not meet the reference condition occurred during the early part of the decade, when there was severe drought in the area. The longest consecutive period of sub-1,500 CFS flows during this period was 12 months, from June 2002 to May 2003. From November 2006 to September 2010, mean monthly flow was greater than 1,500 CFS and for more than half the months, mean monthly flow exceeded 2,500 CFS; continued flows exceeding 2,500 CFS result in maintenance of an excellent fishery (Ruggles, pers. comm., 2012).

Table 27. Mean monthly flows (CFS) for the Bighorn River near St. Xavier, MT, January 2000-December 2010. Sub-2,500 CFS flows are highlighted gray and sub-1,500 CFS flows are bolded (USGS 2011).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	2,637	2,510	2,643	2,508	2,355	2,303	2,327	2,315	1,951	2,082	2,134	2,021
2001	2,148	2,288	2,013	1,984	2,206	2,234	2,346	2,147	1,745	**1,313**	**1,410**	1,545
2002	1,539	1,734	1,575	1,514	1,506	**1,369**	**1,393**	**1,461**	**1,350**	**1,353**	**1,279**	**1,346**
2003	**1,357**	**1,411**	**1,400**	**1,363**	**1,263**	1,774	2,051	1,905	1,719	**1,455**	**1,458**	1,528
2004	1,702	1,489	1,576	1,612	1,696	1,792	1,746	1,588	**1,413**	**1,452**	1,596	1,717
2005	1,548	1,550	**1,489**	**1,488**	**1,471**	4,533	4,422	2,681	2,558	2,561	2,717	2,550
2006	2,537	2,513	2,406	2,424	2,547	2,734	2,213	1,817	1,520	**1,460**	1,593	1,603
2007	1,584	1,518	1,532	1,511	1,566	1,759	2,175	2,169	1,900	1,626	1,919	2,097
2008	2,002	1,950	1,921	1,935	2,653	7,913	4,728	2,771	2,647	2,564	2,539	2,510
2009	2,491	2,432	2,404	2,992	4,093	9,140	8,201	3,206	3,305	3,224	2,894	2,795
2010	2,659	2,440	1,908	1,939	5,432	9,999	5,968	3,342	3,236			
Mean	2,020	1,990	1,900	1,930	2,440	4,140	3,420	2,310	2,120	1,910	1,950	1,970

Trout per River Mile

MTFWP performs yearly sampling on the Bighorn River to determine the abundance of trout. MTFWP uses a boom shocker on a boat for sampling and extrapolates estimates based on those samples using the log-likelihood method (MTFWP 2011). They sample multiple stretches of the river, including an upper reach of the tailwater below Yellowtail Afterbay Dam (4.2 miles [6.7 km] downstream of the 3-Mile Access site). Trout per river mile numbers from this section are similar to those from 3-Mile Access upstream to the Yellowtail Afterbay Dam (Ruggles, pers. comm., 2011).

During typical years, there are approximately 3,000-5,000 trout greater than 10 inches (25.4 cm) per river mile in the upper section of the tailwater (Ruggles, pers. comm., 2011). For the three most recent years of sampling, there were at least 3,000 trout greater than 13 inches (33 cm) per river mile, suggesting even more trout greater than 10 inches (25.4 cm) (MFISH 2011a). Mike Ruggles (pers. comm., 2011) noted that, based on angler accounts and other personal observations, the 2011 tailwater population appeared to be normal. Preliminary data results for a lower section of the tailwater supported these observations (Ruggles, pers. comm., 2011).

Table 28. MTFWP sampling results for the upper section of the Bighorn River, brown trout and rainbow trout, 1986-2010 (MFISH 2011a).

Year	Brown trout per RM	Age/Size sampled	Rainbow trout per RM	Age/Size sampled
1986	7560	All age classes	739	All age classes
1987	9933	All age classes	1016	All age classes
1988	5497	All age classes	960	All age classes
1989	5045	All age classes	1194	All age classes
1990	5223	All age classes	912	All age classes
1991	4334	All age classes	0	No sampling
1992	4991	All age classes	1014	All age classes
1993	3596	All age classes	1048	All age classes
1994	6238	All age classes	1294	All age classes
1995	2683	All age classes	1205	All age classes
1996	3403	All age classes	957	All age classes
1997	4028	All age classes	2318	All age classes
1998	8824	All age classes	1614	All age classes
1999	2112	All age classes	1171	Ages > 1
2000	2104	All age classes	1160	Ages > 2
2001	2380	All age classes	538	Ages > 2
2002	822	All age classes	0	No sampling
2003	492	All age classes	0	No sampling
2004	3109	All age classes	2894	All age classes
2005	1427	Trout > 10 in.	952	Ages > 1
2006	890	Trout > 10 in.	1986	Ages > 1
2007	3490	All age classes	1923	Ages > 1
2008	1950	Trout > 13 in.	2615	Trout > 13 in.
2009	1640	Trout > 14 in.	3223	Trout > 14 in.
2010	948	Trout > 13 in.	2061	Trout > 14 in.

Angling Days

Montana Fish, Wildlife, and Parks conducts angler pressure surveys by mail on a bi-yearly basis. On the Bighorn River, the stretch between RM 70.53-83.7 corresponds to the upper tailwater fishery. Survey data for this stretch of river are available for 1991-2009. Since 1991, fishing pressure on the tailwater has increased (1991: 49,463 ± 2,950; 2009: 109,278 ± 5,408) (Figure 20). In 2009, Montana residents were responsible for about 25% of the fishing pressure on the tailwater (MFISH 2011). On a yearly basis, the tailwater is one of the top ten most fished bodies of water in Montana; in 2009, it ranked third (MFISH 2011).

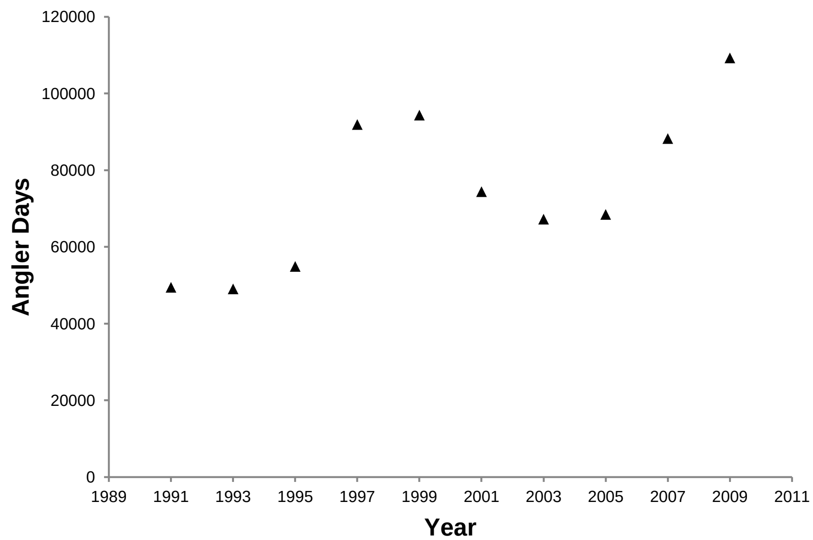

Figure 20. Angler days per year for Bighorn River, river miles 70.53-83.7, 1991-2009 (MFISH 2011).

Angler Success

MTFWP administers a "Fishing Log Program", allowing anglers to provide information regarding their fishing outings. Information provided includes year, angler, fish species caught, number caught, and hours fished. This information can provide a rough estimate of catch-per-unit-effort for years with adequate data. For the Bighorn River, there are 2,674 log entries spanning 1966 to 2010 indicating no fish caught, brown trout caught, or rainbow trout caught; no records are available for 1967. This analysis omitted 6 data years, due to limited samples: 1966 (1 log entry), 1968 (13 log entries), 1977 (8 log entries), 1978 (1 log entry), 1979 (3 log entries), and 1980 (3 log entries). For 1966 and 1968, the reason for the limited data is unknown. For the other omitted years, data were limited due to anglers being unable to access the river. During this time, the Crow tribe limited hunting, fishing, and trapping on the reservation below the dam to tribal members only (MTFWP n.d.). For all other data years, there are at least 24 log entries available that indicate no fish caught or trout caught, with an average of 69.6 log entries per year.

The true mean CPUE (trout per hour for all entries) is 0.88, the yearly mean is 0.825, ranging from 0.51 (2003) to 1.56 (1988). During the early 1970s, CPUE was stable (yearly mean = 0.61, min = 0.56, max = 0.73) (MTFWP 2011). Following the reopening of the fishery to the public in 1980, CPUE increased every year, except for 1983, to an all-time high in 1988 (1.56 trout per hour). From 1983-1985, an average of 18,878 fingerling trout (2-7 inches) were released per year by the MTFWP in the upper reach of the river. The exceptionally high CPUE observed during 1988 is likely an artifact of the extremely low flows, which made fishing very easy (Ruggles, pers. comm., 2011). From 1989 to 2010, CPUE based on fishing logs has been quite variable (mean=0.89, min=0.51, max=1.22), but overall the tailwater fishes quite well compared to most bodies of water in the state (Ruggles, pers. comm., 2011). However, CPUE is not the best measure of abundance, because many factors can alter this measure, such as food supply, flow conditions, and fish health (Ruggles, pers. comm., 2011).

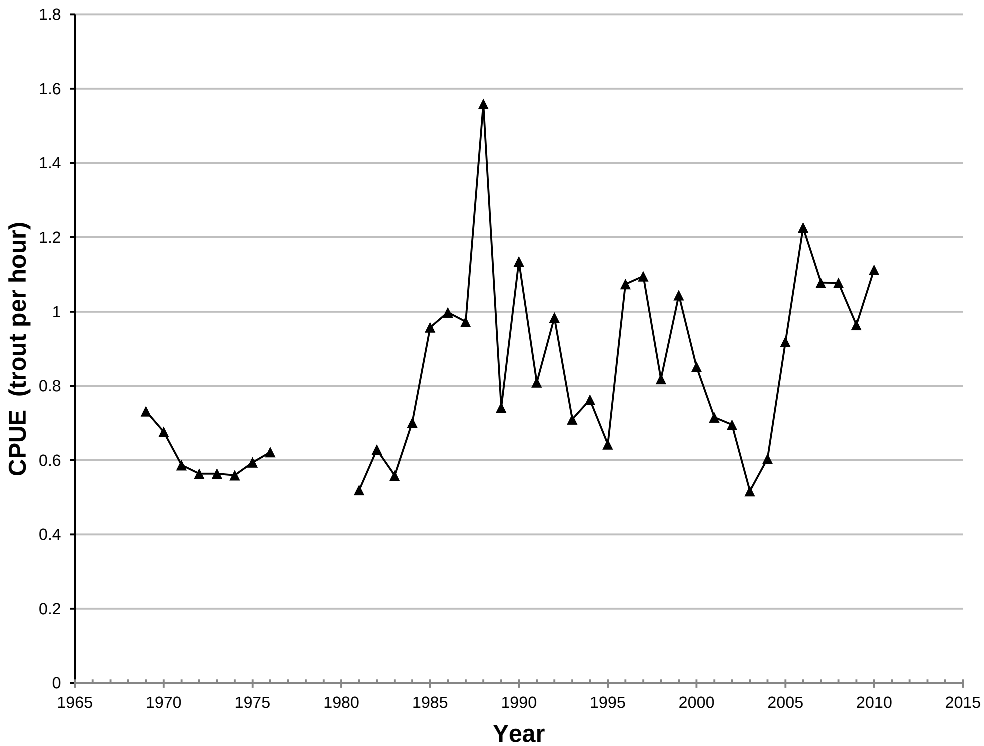

Figure 21. Catch per unit effort for trout on the Bighorn River, 1966-2010, derived from the fishing log data accessed through MTFWP's MFISH database (MTFWP 2011).

<u>Reproduction</u>

Mike Ruggles (pers. comm., 2011) indicated trout per river mile numbers correspond to reproductive success on the tailwater. MTFWP, in cooperation with anglers, Friends of the Bighorn River, Trout Unlimited, and other agencies, works proactively to ensure reproductive success. While the Yellowtail and Yellowtail Afterbay Dams are responsible for the coldwater fishery, they also cause bed degradation and loss of side channel habitat. There is little concern regarding brown trout reproduction, as they are habitat generalists (Ayllón et al. 2010). However, there is concern for rainbow trout, because they are dependent on side channel habitat for reproduction in the tailwater (Ruggles, pers. comm., 2011).

Godaire (2010) performed a geomorphic analysis, examining the loss of side channel habitat on the Bighorn River between Yellowtail Afterbay and the St. Xavier Bridge (21.6 river miles). Godaire (2010) examined USGS gauge data, river cross-sections, longitudinal profile, and 7 years of aerial imagery (1939, 1954, 1961, 1970, 1980, 1991, 2006). Godaire (2010) found that mean bed elevation for the tailwater fluctuated up to 1 meter (3.3 feet) from 1935 to 1965. Then, following dam closure, these fluctuations dampened to 0.36 meters (1.2 feet). The lateral movement of channels has also diminished since dam closure, with little change in location since 1980. Godaire (2010, p. 9) made a specific conclusion regarding loss of side channels and its effect on trout in the tailwater:

> Observations of channel conditions during 2009 indicate that several critical side channels are becoming disconnected with the main channel… These side channels are not being replaced by new channels through channel avulsion [the process in which one channel is abandoned and a new channel is formed]; they are being lost completely.

Another factor encouraging the loss of side channel habitat is exotic invasive species. Russian olive and saltcedar, when present at the head of side channels, inhibit sediment from flowing downstream (Photo 17). Ultimately, this results in the disconnection of side channels without mitigation efforts. Flushing flows and mechanical removals are two actions that remove these species (Ruggles, pers. comm., 2011).

Photo 17. Exotic invasives Russian olive and saltcedar restricting side channel flow on the Bighorn River (Courtesy of Mike Ruggles, MTFWP Fisheries Biologist).

<u>Threats and Stressor Factors</u>

As previously mentioned, saltcedar and Russian olive are two exotic invasive species of concern on the tailwater. Aquatic invasive species (AIS) are a looming threat, but currently not an issue. MTFWP, NPS, and other stakeholders work with recreational river users to prevent the introduction of AIS on the tailwater and Bighorn Lake. Other potential threats to the tailwater fishery include milfoil, exotic mussels, Asian carp spp., and various diseases (i.e., whirling disease and viral hemorrhagic septicemia) (Ruggles, pers. comm., 2011).

Data Needs/Gaps

Continued monitoring of fish populations and AIS is needed in the future in order to assist management of the fishery. Because this is a tailwater fishery and not a free-flowing river, understanding the relationship between flushing flows, channel reestablishment efforts, and the abundance of fish is also important (Ruggles, pers. comm., 2011).

Overall Condition

Flow

Flow (*Significance Level*=3) has a *Condition Level* of 1; since November 2006, mean monthly CFS was greater than the minimum recommended flow of 1,500 CFS and for over half the months, was greater than 2,500 CFS. However, future drought is still a concern regarding the fishery, and condition according to this measure could change rapidly.

Trout per River Mile

For the most recent years of data, trout per river mile (*Significance Level*=3) falls within the expected range of 3,000-5,000 trout greater than 10 inches per river mile, warranting a *Condition Level* of 0.

Reproduction

Reproduction (*Significance Level*=2) is of low concern (*Condition Level*=1), due to invasive species and flow regulation effects on side channel connection. However, many organizations are working to mitigate and prevent channel disconnection.

Angling Days

Angling days (*Significance Level*=2) is of no concern (*Condition Level*=0); as long as there is access and the fishery remains stable, anglers should continue to frequent the tailwater.

Mercury

The condition of mercury (*Significance Level*=1) is unknown. Mercury sampling of fish in the tailwater has not occurred to date, but past surveys indicate high mercury levels in the reservoir. In 2001, an unpublished state survey found high mercury levels in reservoir walleyes (> 1 ppm) (Ruggles, pers. comm., 2011). The fast growth and short life spans of fish in the tailwater do reduce the rate of mercury accumulation, but other conditions may outweigh those positive impacts. Until sampling of tailwater fish occurs, it is unclear whether mercury is affecting the fishery.

Weighted Condition Score

The *Weighted Condition Score* for the Tailwater Trout Fishery component is 0.166 indicating the condition is of low concern. Mike Ruggles (pers. comm., 2011) noted that the tailwater fishery is one of the best fisheries in Montana. This is largely due to stakeholder collaboration on the river to ensure that it continues to produce into the future.

Tailwater Trout Fishery

Measures	SL	CL
• Trout per river mile	3	0
• Flow	3	1
• Reproduction	2	1
• Angling days	2	0
• Mercury	1	N/A

WCS = 0.166

Sources of Expertise
Mike Ruggles, MTFWP Fisheries Biologist
Ken Frazer, MTFWP Fisheries Manager

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4.13 Water Quality

Description

Water quality is a Vital Sign for the GRYN Inventory and Monitoring Program. Measures selected for monitoring in BICA include water chemistry (conductivity, dissolved oxygen, pH, and water temperature), *E. coli*, and aquatic invertebrate assemblages (Jean et al. 2005).

The primary water resources in BICA are the Bighorn River and Bighorn Lake (Photo 18), a reservoir formed on the Bighorn River by the Yellowtail Dam. Tributaries of the Bighorn that flow through the park include Crooked, Layout, and Medicine Creeks. The Shoshone River also flows into Bighorn Lake from the west in the southern half of the park. BICA was established to provide recreational opportunities at Bighorn Lake (Woods and Corbin 2003); therefore, the condition of its water resources is highly important to park management. Water quality impairments could negatively impact popular activities such as fishing, boating, and swimming.

Photo 18. Bighorn Lake as viewed from Horseshoe Bend (photo by Mike Komp, SMUMN GSS 2010).

Measures

- Dissolved oxygen (mean)
- Presence and concentration of *E. coli*
- pH (mean)
- Water temperature (mean)
- Presence of pesticides and herbicides
- Presence/absence of macroinvertebrates

Dissolved Oxygen

Dissolved oxygen (DO) is critical for aquatic life. Fish and zooplankton filter out or "breathe" dissolved oxygen from the water to survive (USGS 2010). Oxygen enters water from the atmosphere or through ground water discharge. As the amount of DO drops, it becomes more difficult for water-based organisms to survive (USGS 2010). The concentration of DO in a water body is closely related to water temperature; cold water holds more DO than does warm water (USGS 2010). Thus, DO concentrations are subject to seasonal fluctuations as low temperatures in the winter and spring allow water to hold more oxygen, and warmer temperatures in the summer and fall allow water to hold less oxygen (USGS 2010).

E. coli

Fecal coliform bacteria such as *E. coli* are an accurate indicator of fecal contamination of water by warm blooded animals. It is tested by counting colonies that grow on agar test plates placed in an incubator for 22-24 hours. High numbers of fecal coliform can be an indicator of harmful bacteria as well as other disease-causing organisms such as viruses and protozoans (USGS 2011).

pH

pH is a measure of the level of acidity or alkalinity of water and is measured on a scale from 0 to 14, with 7 being neutral (USGS 2010). Water with a pH of less than 7.0 indicates acidity, whereas water with a pH greater than 7.0 indicates alkalinity. Aquatic organisms have a preferred pH range that is ideal for growth and survival (USGS 2010). Chemicals in water can change the pH and harm animals and plants living in the water; thus, monitoring pH can be useful for detecting natural and human-caused changes in water chemistry (USGS 2010).

Water Temperature

Water temperature greatly influences water chemistry and the organisms that live in aquatic systems. Not only can it affect the ability of water to hold oxygen, water temperature also affects biological activity and growth within water systems (USGS 2010). All aquatic organisms, from fish to insects to zoo- and phytoplankton, have a preferred or ideal temperature range for existence (USGS 2010). As temperature increases or decreases too far past this range, the number of individuals and species able to live there eventually decreases. In addition, higher temperatures allow some compounds or pollutants dissolve more easily in water and can be more toxic to aquatic life (USGS 2010).

Presence of Pesticides and Herbicides

In areas where agriculture is a major land use, the pesticides and herbicides applied to crops have a likelihood of filtering into streams and rivers through surface and groundwater runoff. Around BICA, agriculture dominates the land use in the Shoshone and Bighorn watersheds and a range of herbicides and pesticides are applied regularly to the corn, sugar beet, bean, and alfalfa crops grown in the region (Woods and Corbin 2003). Although the modern versions of these chemicals do not accumulate in animal tissues the same way as the toxic DDT and DDE forms, these older chemicals still persist in the soils in the watersheds. Runoff from the Shoshone and Bighorn River watersheds can carry these chemicals into BICA where a portion settles out in Bighorn Lake, where they may present a hazard for predator animals and humans through consumption of contaminated fish (Woods and Corbin 2003).

Presence/absence of Macroinvertebrates

Because they spend most or all of their life cycles in water, aquatic macroinvertebrates are well known as indicators of watershed health and the quality of water in aquatic systems (EPA 2011a). Some species are tolerant of pollution or poor water quality, while others are highly sensitive to it. Thus, the presence or absence of tolerant and intolerant species can be an indication of the condition of the water body and water quality (EPA 2011a). The life cycles of many macroinvertebrate species are short (sometimes one season in length), though some species live longer, and many have limited mobility; thus, in a discrete area from year to year, it can be easy to detect population fluctuations that may indicate a change (positive or negative) in water quality (EPA 2011a).

Reference Conditions/Values

The reference condition for water quality in BICA is the EPA water quality criterion for protecting freshwater aquatic life and freshwater bathing and the State of Wyoming and Montana water quality standards for aquatic life. These are specific to dissolved oxygen, *E. coli* bacteria, and pH; Wyoming has specific statewide temperature standards in place, while Montana standards are based on the naturally occurring temperature in each water body.

Table 29. EPA and state water quality standards (from O'Ney et al. 2011).

Parameter	EPA standard	Montana standard	Wyoming standard
Temperature	<20°C (coldwater permanent fisheries)	<19.4°C (coldwater fisheries) <26.6 °C (warmwater fisheries)*	<20°C (coldwater fisheries) <30°C (warmwater fisheries)
Dissolved oxygen	≥4 mg/L (coldwater permanent fisheries)	same as EPA	same as EPA
pH	6.5 – 9.0 (freshwater)	6.5 – 9.0	6.5 - 8.5
E. coli	≤126 CFU/100 ml	N/A	same as EPA

*from Sigler 2011

Data and Methods

In 1998, the NPS published the results of surface-water quality data retrievals for BICA using six of the EPA national databases: Storage and Retrieval (STORET) water quality database management system, River Reach File (RF3), Industrial Facilities Discharge (IFD), Drinking Water Supplies (DRINKS), Water Gages (GAGES), and Water Impoundments (DAMS) (NPS 1998). The retrieval located five industrial/municipal discharger, one drinking water intakes, 16 active or inactive USGS stream gages, and seven water impoundments. Results of the STORET query yielded 73,531 observations for various parameters collected between 1947 and 1997 at 210 monitoring stations run by the NPS, USGS, EPA, and the Wyoming and Montana Departments of Environmental Quality (DEQ). Eighty-seven of these 210 stations were within the BICA boundary. While much of this station data consists of one-time or intensive single-year sampling efforts, three stations within or near the park provide longer-term data (NPS 1998). The stations with the longest record are: 1) Bighorn River near St. Xavier, MT (BICA 0180); 2) Shoshone River near Lovell, WY (BICA 0019); 3) Bighorn River at Kane, WY (BICA 0002). The first station is inside BICA, at the park's northern tip, while the other two are just upstream of its boundaries. This assessment will focus on these three stations.

Woods and Corbin (2003) repeated the NPS (1998) baseline water quality inventory retrieval process with the same EPA databases several years later. The authors focused their analysis on one representative station in each of the three sub-basins influencing BICA (Bighorn Lake, Shoshone, and Lower Bighorn Lake) as well as seven sites on Bighorn Lake itself (BICA 0042, 0044, 0049, 0050, 0051, 0052, and 0053). The USGS gaging station on the Bighorn River at Kane, Wyoming (BICA 0002) was selected to represent the Bighorn Lake sub-basin, while the USGS gaging stations on the Shoshone River at Kane (BICA 0026) and on the Bighorn River at St. Xavier, MT (BICA 0180) were chosen to represent the Shoshone and Lower Bighorn Lake (below Yellowtail Dam) sub-basins respectively (Woods and Corbin 2003).

Photo 19. Water quality sampling in BICA (NPS photo).

The GRYN began monitoring water bodies classified as "water-quality impaired" by the states of Wyoming and Montana in 2005 (O'Ney et al. 2009a). For BICA, these water bodies are the Shoshone River (near Lovell, WY) and the Bighorn River at St. Xavier, MT. Standard operating procedures were outlined for measuring key parameters such as water chemistry (temperature, pH, DO), *E. coli,* and macroinvertebrates. These can be found in O'Ney (2006). In 2006, water quality sampling was expanded in the park to include a total of seven sites (excluding springs) regularly monitored as part of the Vital Signs monitoring program (Table 30). The GRYN utilizes a "targeted sampling design", where sites are chosen either "to continue historical trend data from the USGS" or to investigate anthropogenic impacts (e.g., grazing, cattle trailing, campgrounds) (O'Ney et al. 2009b, p. 3). Sites are sampled at least quarterly each year (March, May, September, and December). Results of the GRYN monitoring program are presented in O'Ney et al. (2009a, b, 2011) and Sigler (2011). Additional data were collected for Crooked Creek by the WY Department of Environmental Quality in August of 2010 (WY DEQ 2010). USGS studies of the Yellowstone River Basin, which includes the Bighorn River, also provided information regarding *E. coli* and pesticides for the Bighorn River at Kane site between 1999 and 2001 (Miller et al. 2005).

Table 30. Sampling stations in and near BICA for the GRYN Vital Signs monitoring program (O'Ney et al. 2009a).

Station Name	Station ID	Comparable USGS gaging station
Bighorn River at Xavier, MT	BICA_BHR1	BICA 0180
Bighorn River at Kane, WY	BICA_BHR2	BICA 0002
Shoshone River near Lovell, WY	BICA_SHR2	BICA 0019
Crooked Creek, WY	BICA_CCR1	NA
Layout Creek below road, MT	BICA_LCR2	NA
North Trail Creek, MT	BICA_TRC1	NA
Davis Creek, MT	BICA_DACR1	NA

Simmons et al. (2004) compiled existing macroinvertebrate data for all GRYN parks, including BICA. The authors also discussed sampling design and made recommendations for the GRYN monitoring program. Macroinvertebrate data was gathered from five water bodies in BICA between 2006 and 2009 but has not yet been published. This data, along with data from a 2002 study (Arnold and Koel 2004) was obtained for analysis from Jeff Arnold, an Aquatic Ecologist with the NPS.

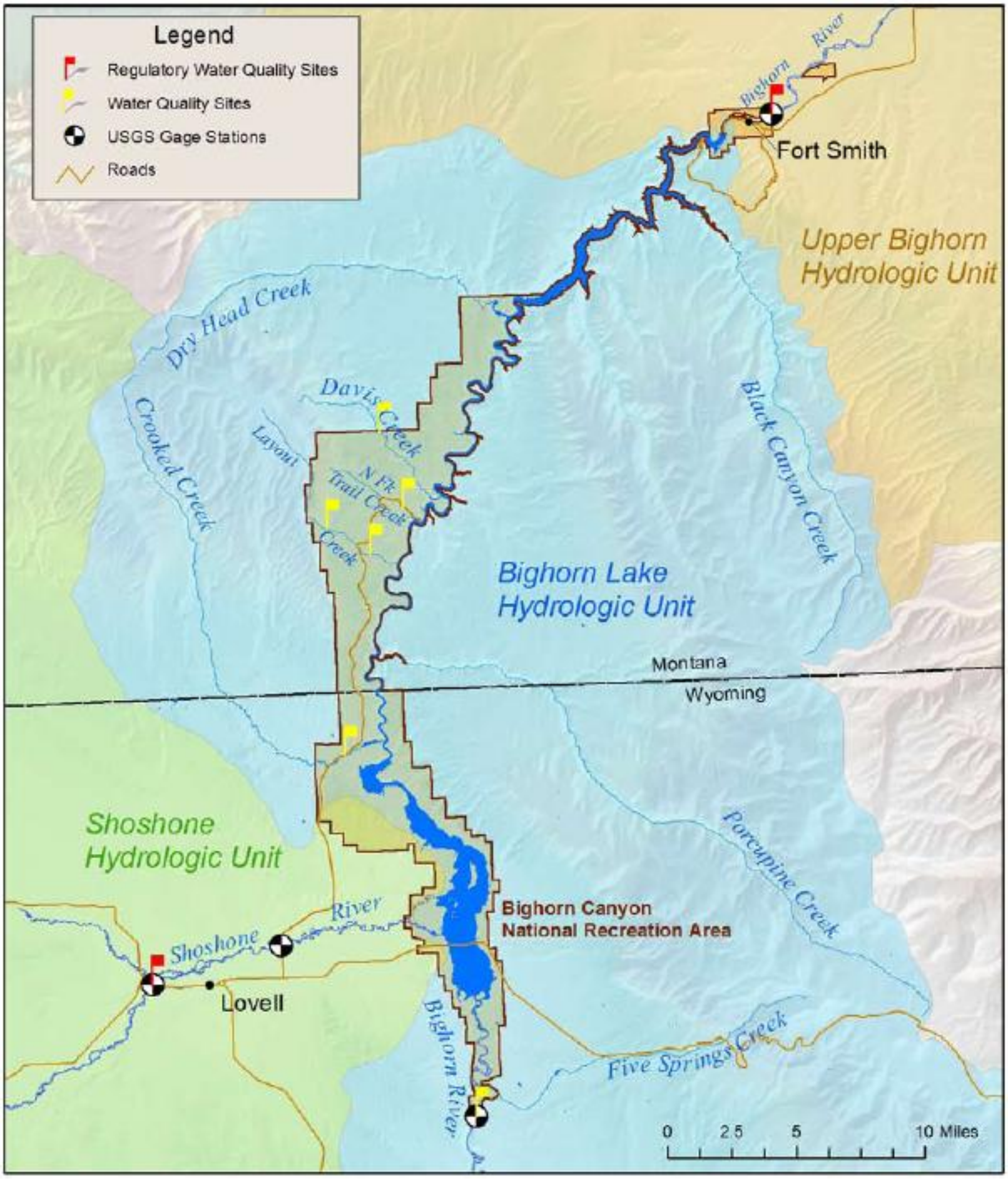

Figure 22. Sampling locations in BICA for the GRYN water quality monitoring program (O'Ney et al. 2009b).

Current Condition and Trend

Dissolved Oxygen (DO)

According to NPS (1998), DO was sampled 708 times between 1957 and 1997 at 31 different stations. Forty-seven measurements from nine stations in Bighorn Lake (all at depths below 15

m) were below the EPA standard of 4 mg/L. The results for the selected long-term stations from NPS (1998) as well as from Woods and Corbin (2003) are summarized in Table 31. Woods and Corbin (2003) selected the station on the Shoshone River at Kane, WY (BICA 0026) to represent the Shoshone sub-basin rather than the station near Lovell.

Table 31. Dissolved oxygen measurements (mg/L) from long-term monitoring stations in or near BICA (NPS 1998, Woods and Corbin 2003).

Station	Observations	Median	Mean	Range
Bighorn at Kane (BICA 0002)				
NPS 1998	122	9.85	9.91	6.6-14
Woods and Corbin 2003	145	--	9.7	1.7-14
Shoshone River				
NPS 1998 (near Lovell, BICA 0019)	38	11.15	11.08	7.5-14.2
Woods and Corbin 2003 (at Kane, BICA 0026)	42	--	10.3	6.7-13.2
Bighorn near St. Xavier (BICA 0180)				
NPS 1998	6	11.3	11.47	10-12.8
Woods and Corbin 2003	18	--	11.5	9.6-13.2

Woods and Corbin (2003) also summarized water quality data for seven stations on Bighorn Lake. These stations are all located near the northern end of upper Bighorn Lake in Wyoming. Three samples from these sites ranged from 8 to 8.6 mg/L with a mean of 8.3 mg/L (Woods and Corbin 2003).

The GRYN has been monitoring DO at seven sites in or near BICA since 2006. During this time, all DO measurements have met the EPA and state standards of 4 mg/L. The 2007 and 2010 measurements for each site are shown in Table 32.

Table 32. Dissolved oxygen measurements at the seven GRYN monitoring sites in or near BICA (Schmitz 2008, Sigler 2011).

Station	Mean	Range
Bighorn near St. Xavier (BHR1)		
2007	11.7	9.9-13.0
2010	10.91	8.34-13.10
Bighorn River at Kane (BHR2)		
2007	10.2	8.1-12.6
2010	10.02	8.42-13.21
Shoshone River near Lovell (SHR2)		
2007	12.4	10.7-14.9
2010	10.52	8.80-12.61
Crooked Creek (CCR1)		
2007	9.9	8.1-11.7
2010	10.35	8.20-13.23
Davis Creek (DACR1)		
2007	8.7*	--
2010		
Layout Creek below road (LCR2)		
2007	10.2	8.9-11.8
2010	9.20	8.40-10.70
North Trail Creek (TRC1)		
2007	9.7	8.9-10.5
2010	9.68	8.63-11.10

*Only one sample was taken at Davis Creek in 2007 as the site was dry for most of the year. Results from 2010 were not available.

E. coli

Early water quality sampling focused on fecal coliform bacteria as a group rather than specifically on *E. coli*. Miller et al. (2005) addressed *E. coli* concentrations in the BICA area in a USGS water quality assessment of the Yellowstone River Basin. Eighteen samples were taken from the Bighorn River at Kane site from 1999-2001. The median *E. coli* concentration was just over 50 col/100 mL (Figure 23). However, two samples exceeded 400 col/100 mL and one was above 576 col/100 mL, the EPA standard for infrequent recreational contact (Miller et al. 2005).

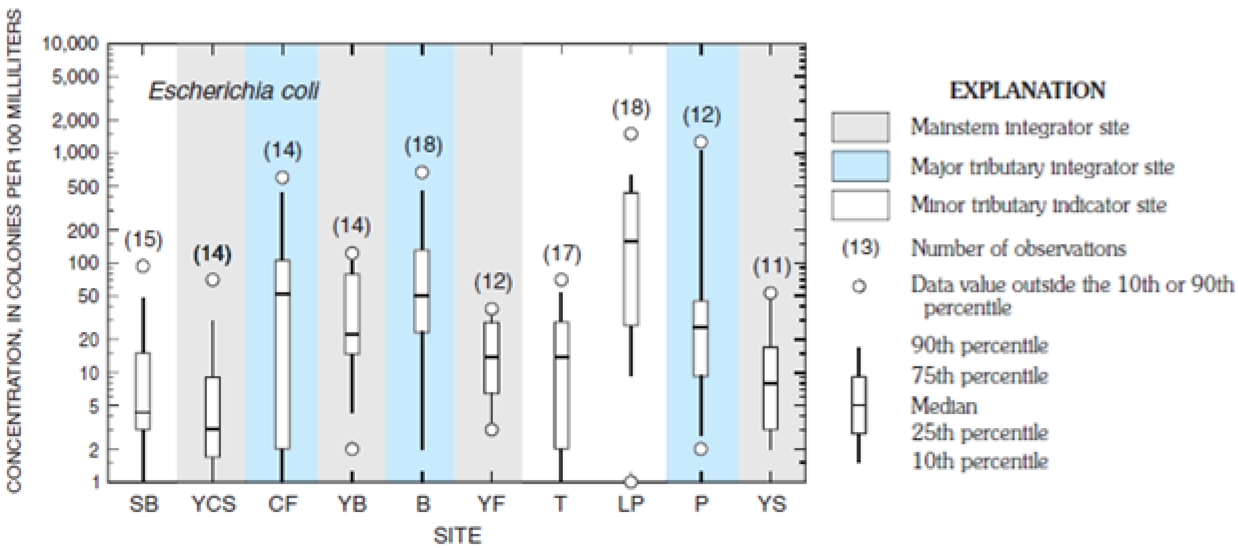

Figure 23. *E. coli* concentrations in the Yellowstone River Basin, 1999-2001. The Bighorn River at Kane site near BICA is represented with a "B" (Miller et al. 2005).

E. coli has also been sampled as part of the GRYN monitoring protocol. Concentrations within BICA waters have primarily met the EPA standard (<126 cfu/100 mL), with the exception of Crooked Creek, which passes through agricultural and mining areas before entering the park (O'Ney et al. 2009b, Table 33). The Shoshone River near Lovell regularly exceeds *E. coli* standards and has been listed as a 303(d) impaired waterway for fecal coliform contamination since 2002 (O'Ney et al. 2011). All samples taken from the Shoshone in 2009 and 2010 exceeded the EPA standard; likely sources of contamination include sewage, agricultural and wildlife waste, and domestic waste from nearby populated areas (O'Ney et al. 2009b).

Table 33. *E. coli* concentrations (cfu/100 mL) at sampling sites in or near BICA (O'Ney 2009, O'Ney et al. 2009a,b, 2011; WY DEQ 2010, EPA 2011b).

Site	Samples exceeding EPA standard	Mean	Range
Bighorn River near St. Xavier			
Oct 2005- Dec 2006	0%	13.5	7-20
Bighorn River at Kane			
2006 (single sample)	0%	47	--
Shoshone River near Lovell			
June-Sept 2005	100%	772.7	300-1,600
Oct 2005- Dec 2006	93%	567.7	430-930
2007	100%	536.9	299.6-633.3
2008	25%	123.1	4-157
2009	100%	417.7	372-401
2010	100%	590.0	238.2-2,419.6
Park streams			
Oct 2005- Dec 2006	29% (Crooked Creek)	66.21	23-309
Crooked Creek			
Oct 2005- Dec 2006	100%	237	165-309
August 2010 (single sample)	--	307.6	--

pH

NPS (1998) indicates that pH was reported 2,268 times between 1947 and 1997 at 159 different monitoring stations. Six measurements at six different stations in and near BICA fell outside the EPA standard of 6.5-9.0 (four above 9.0 and two below 6.5). The highest concentration, 9.7, occurred on the Bighorn River at Kane in 1979, while the lowest value of 6.3 was observed in a stream south of Sunlight Canal (BICA 0017) in 1976. Results for the selected long-term stations from NPS (1998) and from Woods and Corbin (2003) are presented in Table 34.

Table 34. pH measurements from long-term monitoring stations in or near BICA (NPS 1998, Woods and Corbin 2003).

Location	Observations	Median	Mean	Range
Bighorn at Kane (BICA 0002)				
NPS 1998	514	7.8	7.86	6.8-9.7
Woods and Corbin 2003	545	--	7.9	6.8-9.7
Shoshone River				
NPS 1998 (near Lovell, BICA 0019)	234	8	7.98	6.5-8.7
Woods and Corbin 2003 (at Kane, BICA 0026)	228	--	7.8	7-8.5
Bighorn near St. Xavier (BICA 0180)				
NPS 1998	162	8	7.92	6.6-8.5
Woods and Corbin 2003	162	--	7.9	6.6-8.5

At the seven Bighorn Lake stations summarized by Woods and Corbin (2003), nine total samples yielded a mean pH of 8.1 with a range from 7.7 to 8.6.

At the seven sites monitored by the GRYN within the past 5 years, all measurements have fallen within the EPA standard of 6.5-9.0 and within the respective state standards. Results from 2007 and 2010 sampling are shown in Table 35.

Table 35. pH measurements at the seven GRYN monitoring sites in or near BICA (Schmitz 2008, Sigler 2011).

Station	Mean	Range
Bighorn near St. Xavier (BHR1)		
2007	7.87	7.68-8.06
2010	7.85	7.69-8.14
Bighorn River at Kane (BHR2)		
2007	7.82	7.25-8.36
2010	8.32	8.02-8.58
Shoshone River near Lovell (SHR2)		
2007	8.43	8.10-8.80
2010	8.38	7.99-8.78
Crooked Creek (CCR1)		
2007	8.11	7.96-8.32
2010	8.18	7.97-8.42
Davis Creek (DACR1)		
2007	8.21*	--
2010		
Layout Creek below road (LCR2)		
2007	8.11	7.91-8.29
2010	8.22	8.04-8.34
North Trail Creek (TRC1)		
2007	7.88	7.47-8.14
2010	8.03	7.89-8.24

*Only one sample was taken at Davis Creek in 2007 as the site was dry for most of the year. Results from 2010 were not available.

Water Temperature

According to NPS (1998), water temperature was sampled 995 times between 1947 and 1997 at the three selected long-term stations (BICA 0002, 0019, and 0180). Temperatures ranged from 0°C to 26.5°C, with the highest value occurring in the Bighorn River at Kane, WY. All of these stations experienced temperatures above the EPA standard of 20°C for coldwater fisheries. The results for the selected long-term stations from NPS (1998) and Woods and Corbin (2003) are summarized in Table 36.

Table 36. Temperature readings (°C) from long-term monitoring stations in or near BICA (NPS 1998, Woods and Corbin 2003).

Station	Observations	Median	Mean	Range
Bighorn at Kane (BICA 0002)				
NPS 1998	424	12	11.2	0-26.5
Woods and Corbin 2003	424	--	11.2	0-26.5
Shoshone River				
NPS 1998 (near Lovell, BICA 0019)	313	10.5	10.04	0-25.5
Woods and Corbin 2003 (at Kane, BICA 0026)	82	--	11.7	0-25.5
Bighorn near St. Xavier (BICA 0180)				
NPS 1998	258	7	8.35	1-21.5
Woods and Corbin 2003	295	--	8.6	1-21.5

At the seven Bighorn Lake stations summarized by Woods and Corbin (2003), 197 temperature readings ranged from 0.3 to 28.1°C with a mean of 15.7°C.

Of the seven sites monitored by the GRYN since 2006, one reading taken in Crooked Creek in 2009 and one reading in the Bighorn River at Kane in July 2010 exceeded the EPA standard of 20°C for coldwater fisheries (Sigler 2011, O'Ney et al. 2011). Results from 2007 and 2010 sampling are presented in Table 37. A single measurement taken by the Wyoming DEQ at Crooked Creek in August of 2010 also exceeded the EPA standard with a temperature reading of 25.19°C (WY DEQ 2010).

Table 37. Water temperature measurements (°C) at the seven GRYN monitoring sites in or near BICA (Schmitz 2008, Sigler 2011).

Station	Mean	Range
Bighorn near St. Xavier (BHR1)		
2007	6.6	3.5-11.3
2010	7.92	2.12-16.79
Bighorn River at Kane (BHR2)		
2007	7.8	0-16.6
2010	12.92	0.05-23.86
Shoshone River near Lovell (SHR2)		
2007	10.7	0-20.4
2010	11.59	1.19-19.63
Crooked Creek (CCR1)		
2007	9.6	1.9-15.3
2010	10.52	1.57-16.77
Davis Creek (DACR1)		
2007	11.2*	--
2010		
Layout Creek below road (LCR2)		
2007	6.6	1.4-11.9
2010	11.87	8.51-15.95
North Trail Creek (TRC1)		
2007	9.0	5.7-11.6
2010	10.20	6.50-14.36

*Only one sample was taken at Davis Creek in 2007 as the site was dry for most of the year. Results from 2010 were not available.

Macroinvertebrates

Prior to 2000, macroinvertebrate data from BICA water bodies was relatively sparse. In an effort to compile existing data for the park, Simmons et al. (2004) found just nine samples from seven different sites. The authors used this information to compile a taxa list for BICA and calculate several diversity indices for Crooked Creek, along with other parks in the GRYN (Table 38).

Table 38. Macroinvertebrate taxa richness and diversity indices for Crooked Creek in BICA in comparison to water bodies in other GRYN parks (Simmons et al. 2004). For these indices, a higher number indicates higher diversity.

Site	Taxa richness	Pielou's evenness	Shannon's diversity	Simpson's diversity
Crooked Creek (1)	18	0.809	2.339	0.8728
Crooked Creek (2)	19	0.813	2.392	0.8691
Yellowstone (range)	9-36	0.4-0.868	1.01-2.736	0.5551-0.9154
Grand Teton (range)	5-36	0.256-0.868	0.532-2.686	0.2138-0.9051

The GRYN sampled macroinvertebrates in the Bighorn River near St. Xavier, MT, in the fall of 2005. Total taxa richness at this site was 27 with a Shannon diversity index of 2.22 and an evenness of 0.65 (O'Ney et al. 2009b). However, the scarcity of taxa from the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT), which are intolerant of low water quality, indicate water quality impairment (O'Ney et al. 2009b). Since 2007, the GRYN has sampled macroinvertebrates in five rivers and streams in or near BICA. Researchers have used this data to update the BICA taxa list (Appendix F) and track community composition by stream (Table 39, Table 40, Figure 24). Taxa richness varied from 42 in the Shoshone River to 78 in Layout Creek. EPT taxa richness was also lowest in the Shoshone and highest in Layout Creek at 8 and 24 taxa respectively (NPS 2011). The Bighorn and Shoshone Rivers had the highest percentage of taxa considered tolerant of water quality impairments at 63% while only Layout and Trail Creeks supported taxa considered intolerant of impairment. Shannon's diversity indices ranged from 2.013 (Shoshone) to 2.666 (Layout), while evenness ranged from 0.620 (Shoshone) to 0.730 (Crooked) (NPS 2011, Table 40).

Table 39. Common macroinvertebrate taxa in BICA by stream (NPS 2011).

River/Stream	Common taxa
Bighorn River	*Caecidotea* sp., *Cricotopus* sp., *Cheumatopsyche* sp.
Crooked Creek	*Cricotopus* sp., *Cheumatopsyche* sp., *Orthocladius* sp.
Layout Creek	*Ostracoda* sp., *Paraleptophlebia* sp., Turbellaria
Shoshone River	*Baetis tricaudatus, Tricorythodes minutus*, *Cricotopus* sp.
Trail Creek	*Baetis tricaudatus*, *Zapada cinctipes*, *Hydropsyche* sp.

Table 40. Macroinvertebrate taxa recorded in five rivers or streams within BICA, 2007-2009 (the Bighorn River was also sampled in 2006 while Crooked and Layout Creeks were sampled in 2002 as well). Two sites were sampled along the Bighorn and Layout Creek while only one site was sampled on the remaining three water bodies (NPS 2011).

Taxa	Bighorn River	Crooked Creek	Layout Creek	Shoshone River	Trail Creek
Non-Insect					
Turbellaria	x		x	x	x
Oligochaeta	x	x	x	x	x
Erpobdellidae	x			x	
Lymnaeidae	x	x			
Nematoda			x	x	
Physa/Physella sp.		x			
Physa sp.	x	x	x	x	x
Pisidium sp.	x				
Potamopyrgus antipodarum	x				
Sphaerium sp.	x				
Chydoridae	x				
Glossiphoniidae	x				
Ostracoda	x	x	x		x
Crangonyx sp.	x				
Gammarus sp.	x			x	x
Hyalella sp.	x	x			
Caecidotea sp.	x			x	x
Acari	x	x	x	x	x
Insect					
Argia sp.		x			
Ophiogomphus sp.	x	x			
Acentrella sp.		x			
Acentrella insignificans	x	x		x	
Ameletus sp.			x		
Baetidae	x	x			
Baetis bicaudatus			x		
Baetis tricaudatus	x	x	x	x	x
Camelobaetidius sp.	x				
Camelobaetidius warreni	x				
Cercobrachys sp.	x				
Cinygmula sp.			x		
Diphetor hageni			x		x
Drunella doddsi				x	
Ephemerella excrusians	x			x	
Fallceon quilleri	x				
Mccaffertium sp.	x				
Neochoroterpes sp.	x				
Paraleptophlebia sp.			x		
Tricorythodes explicatus	x	x			

Table 40. Macroinvertebrate taxa recorded in five rivers or streams within BICA, 2007-2009 (the Bighorn River was also sampled in 2006 while Crooked and Layout Creeks were sampled in 2002 as well). Two sites were sampled along the Bighorn and Layout Creek while only one site was sampled on the remaining three water bodies (NPS 2011). (continued)

Taxa	Bighorn River	Crooked Creek	Layout Creek	Shoshone River	Trail Creek
Insect (continued)					
Tricorythodes minutus	x	x		x	x
Capniidae			x		x
Chloroperlidae			x		
Hesperoperla pacifica			x		x
Isoperla sp.		x	x		x
Malenka sp.			x		x
Perlodidae			x		
Sweltsa sp.			x		
Zapada cinctipes			x		x
Corixidae	x				
Agraylea sp.		x			
Amiocentrus aspilus	x				
Brachycentrus americanus			x		
Brachycentrus occidentalis	x	x			
Culoptila sp.	x				
Cheumatopsyche sp.	x	x		x	
Dolophilodes sp.			x		
Hesperophylax sp.		x	x		
Hydropsyche sp.	x	x	x	x	x
Hydroptila sp.	x	x			x
Lepidostoma sp.			x		
Limnephilidae		x			
Micrasema sp.			x		
Neophylax splendens			x		
Oecetis sp.	x				
Ochrotrichia sp.		x	x		
Rhyacophila brunnea/vemna group			x		
Petrophila sp.	x	x			
Dubiraphia sp.	x	x		x	
Dytiscidae		x			x
Haliplus sp.	x				
Helichus sp.		x			
Heterlimnius sp.			x		x
Hydrophilidae		x			
Hydroporinae			x		x
Microcylloepus sp.	x			x	
Narpus sp.			x		x
Optioservus sp.		x	x	x	x

Table 40. Macroinvertebrate taxa recorded in five rivers or streams within BICA, 2007-2009 (the Bighorn River was also sampled in 2006 while Crooked and Layout Creeks were sampled in 2002 as well). Two sites were sampled along the Bighorn and Layout Creek while only one site was sampled on the remaining three water bodies (NPS 2011). (continued)

Taxa	Bighorn River	Crooked Creek	Layout Creek	Shoshone River	Trail Creek
Insect (continued)					
Postelichus sp.		x	x		
Caloparyphus sp.	x				x
Ceratopogoninae	x	x			x
Chelifera/Metachela sp.		x	x		
Dicranota sp.			x		x
Dixa sp.			x		x
Dixidae			x		
Forcipomyiinae		x	x		
Gonomyia sp.					x
Hemerodromia sp.	x	x		x	x
Hexatoma sp.			x		x
Limnophila sp.			x		x
Limnophora sp.		x	x		
Muscidae	x	x			
Neoplasta sp.			x		x
Ormosia sp.			x		x
Pericoma sp.	x		x		
Pericoma/Telmatoscopus sp.			x		
Ptychoptera sp.			x		
Simulium sp.	x	x	x	x	x
Stratiomyiidae unknown				x	
Tipula sp.			x		x
Chironomidae - pupae	x	x	x	x	x
Alatanypus sp.			x		
Apedilum sp.		x			
Brillia sp.		x	x	x	
Chironomus sp.				x	
Cladotanytarsus sp.	x			x	
Corynoneura sp.		x	x		x
Cricotopus sp.	x	x	x	x	x
Cricotopus bicinctus group	x			x	
Cricotopus trifascia group	x	x		x	
Cryptochironomus sp.	x	x		x	
Diamesa sp.			x		
Dicrotendipes sp.	x	x			x
Epoicocladius sp.			x		
Eukiefferiella sp.	x	x	x		x
Eukiefferiella claripennis group		x	x	x	x
Eukiefferiella devonica group	x	x	x		x

Table 40. Macroinvertebrate taxa recorded in five rivers or streams within BICA, 2007-2009 (the Bighorn River was also sampled in 2006 while Crooked and Layout Creeks were sampled in 2002 as well). Two sites were sampled along the Bighorn and Layout Creek while only one site was sampled on the remaining three water bodies (NPS 2011). (continued)

Taxa	Bighorn River	Crooked Creek	Layout Creek	Shoshone River	Trail Creek
Insect (continued)					
Eukiefferiella gracei group					x
Heleniella sp.			x		
Hydrobaenus sp.			x		
Limnophyes sp.		x	x		
Micropsectra sp.	x	x	x	x	x
Microtendipes sp.				x	
Microtendipes pedullus group				x	
Orthocladius Complex	x	x	x	x	x
Orthocladius sp.	x	x	x	x	
Pagastia sp.			x		
Parakiefferiella sp.	x	x		x	
Paramerina sp.		x			
Parametriocnemus sp.		x	x		
Paratanytarsus sp.		x			
Parorthocladius sp.			x		
Pentaneura sp.		x	x		x
Phaenopsectra sp.	x			x	
Polypedilum sp.	x	x	x		
Potthastia Longimana group	x				x
Procladius sp.		x			
Pseudochironomus sp.	x				
Pseudosmittia sp.		x			
Psilometriocnemus sp.			x		
Radotanypus sp.			x		x
Rheocricotopus sp.			x		
Rheotanytarsus sp.		x		x	
Stictochironomus sp.	x			x	
Stilocladius sp.			x		
Tanytarsus sp.	x	x	x	x	x
Thienemanniella sp.		x	x	x	x
Thienemannimyia Complex	x	x	x	x	x
Tvetenia Bavarica group		x	x		x
Virgatanytarsus sp.					x
Total Taxa	67	66	78	42	52
Total EPT taxa	19	15	24	8	11
Tolerant Taxa (%)	63.55	27.36	4.69	63.39	28.73
Intolerant Taxa (%)	0	0	0.84	0	0.27
Shannon's diversity	2.145	2.543	2.666	2.013	2.230
Evenness	0.657	0.730	0.728	0.620	0.653

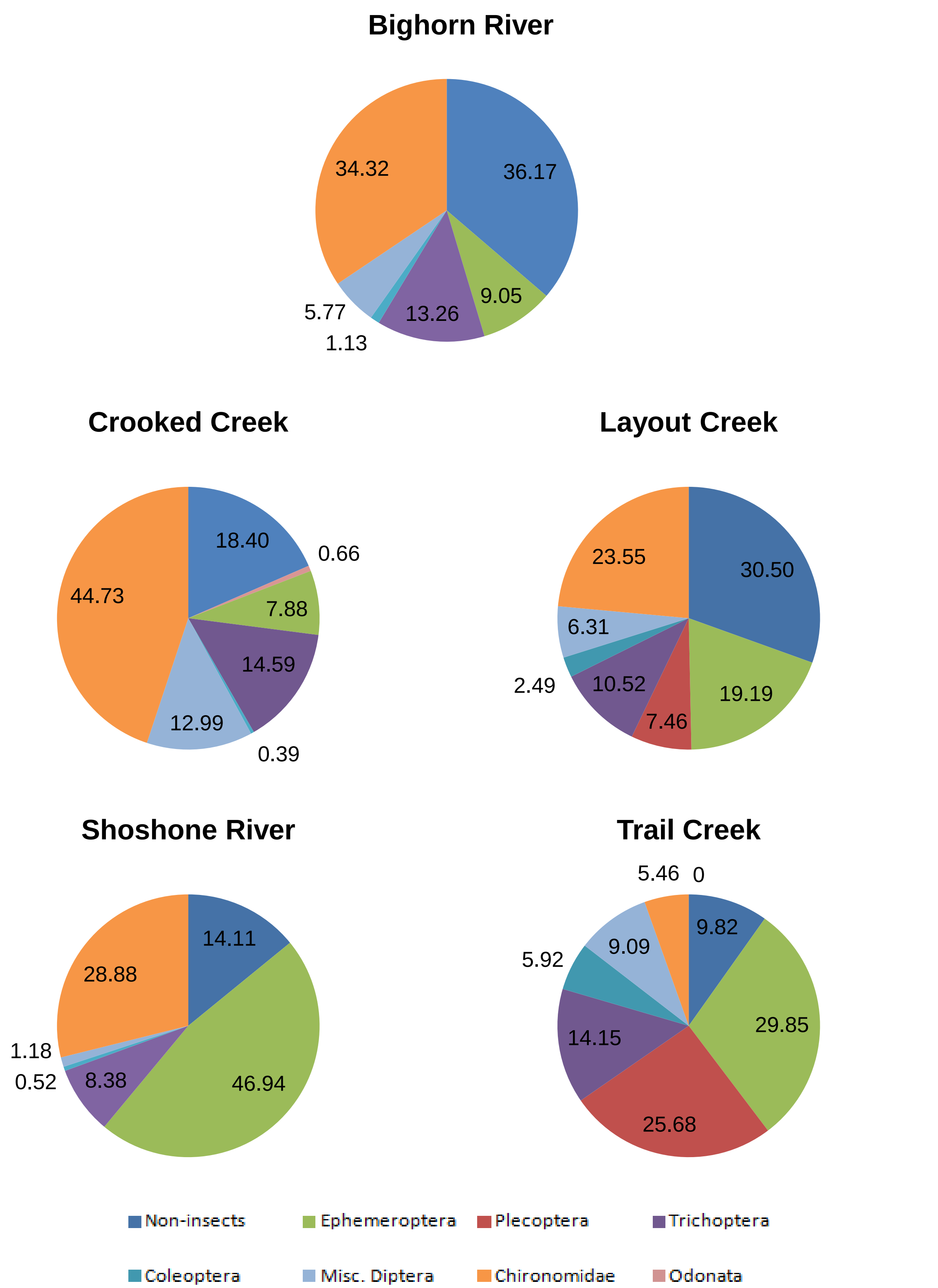

Figure 24. Macroinvertebrate community composition of five waterways in BICA. Groups that comprised <0.25% are not included (NPS 2011).

Threats and Stressor Factors

Most of the threats to BICA's water quality originate outside of the park's boundaries. These include ranching and agricultural activities, oil and gas development, and municipal and industrial wastewater discharge (NPS 1998, Woods and Corbin 2003). Grazing by both livestock and wild ungulates can elevate bacteria and nutrient levels in streams, as well as degrade stream banks (O'Ney et al. 2009b). Atmospheric deposition of pollutants from industry (e.g., mercury), energy development, and agriculture is a growing concern. Increased recreational use within BICA (camping, hiking, boating, etc.) could also threaten water quality (Woods and Corbin 2003, O'Ney et al. 2009b).

Park managers are also concerned about rising water temperatures, reduced flow on Crooked Creek, and *E. coli* concentrations in the Shoshone River. If large amounts of bacteria enter Bighorn Lake, causing elevated levels of *E. coli*, recreational activities in the park (particularly swimming) could be threatened.

Data Needs/Gaps

Little information is available regarding pesticides and other contaminants in the park's waters. The only existing published data comes from the Bighorn River at Kane from 1999-2001 (Miller et al. 2005). No water sampling exists more recently or further into the park. However, recent sediment sampling at Horseshoe Bend on Bighorn Lake did not detect any pesticides (Bromley, pers. comm., 2012). Contamination of aquatic systems is an important issue, given the growing concern over oil and gas development and atmospheric deposition from industrial and agricultural sources. Sampling for *E. coli* in Bighorn Lake, for example near the Shoshone River and Crooked Creek, could help managers understand how these tributaries impact lake bacteria levels. Finally, it will be important to continue the GRYN monitoring program so that any changes or trends in BICA water quality can be detected and investigated.

Overall Condition

Dissolved Oxygen

The project team defined the *Significance Level* for dissolved oxygen as a 3. Since GRYN monitoring began in 2006, all DO measurements have met the EPA and state standards of 4 mg/L. Therefore, dissolved oxygen is assigned a *Condition Level* of 0, indicating no concern.

E.coli

The project team defined the *Significance Level* for *E. coli* as a 3. While *E. coli* concentrations within BICA have typically met the EPA standard in limited sampling (with the exception of Crooked Creek), all samples from the Shoshone River just upstream of the park in 2009 and 2010 exceeded that standard. If these bacteria reach Bighorn Lake, the impact on recreational activities (especially swimming) could be serious. *E. coli* is therefore of moderate concern (*Condition Level* = 2).

pH

The project team defined the *Significance Level* for pH as a 3. All of the pH measurements taken since 2006 as part of the GRYN monitoring program have fallen within EPA and state standards. As a result, this measure is assigned a *Condition Level* of 0, indicating no concern.

Water Temperature
The project team defined the *Significance Level* for water temperature as a 3. The majority of temperature readings taken by the GRYN monitoring program have met EPA and state standards for coldwater fisheries. In 2010, just one measurement in the Bighorn River at Kane and one in Crooked Creek exceeded the standards. Water temperature is therefore of low concern (*Condition Level* = 1).

Presence of Pesticides
The project team defined the *Significance Level* for presence of pesticides as a 1. The USGS tested 21 water samples from the Bighorn River at Kane for pesticides from 1999-2001 (Miller et al. 2005). Sixteen different pesticides or their breakdown products were detected, although most were at low concentrations (Table 41). The most common compounds were the herbicides atrazine (and its breakdown product, deethylatrazine), metolachlor, and triallate (Miller et al. 2005). No information was available regarding pesticides in other BICA waterways or further downstream on the Bighorn River. As a result, a *Condition Level* could not be assigned for this measure.

Table 41. Pesticides detected in the Bighorn River at Kane, WY, 1999-2001. Herbicides are in plain text, insecticides are in bold, and breakdown products are italicized (Miller et al. 2005).

Pesticide compound	Percent of samples detected	Detected above 0.01 µg/L
Atrazine	81	
Carbaryl	4.8	
Carbofuran	4.8	x
Chlorpyrifos	14	
Cyanzine	19	x
DCPA	9.5	
Deethylatrazine	43	
EPTC	14	x
Ethafluralin	4.8	
Malathion	24.0	x
Metolachlor	38.0	x
Prometon	29.0	
Tebuthiuron	24.0	
Terbufos	4.8	x
Triallate	33.0	
Trifluralin	4.8	

Macroinvertebrates
The project team defined the *Significance Level* for macroinvertebrates as a 3. Prior to 2000, macroinvertebrate data for BICA water bodies was extremely limited. Since 2007, the GRYN has been regularly sampling macroinvertebrates in five BICA waterways. While species richness is relatively high, the absence of taxa considered intolerant of water quality impairment is a cause for concern. Therefore, the *Condition Level* for macroinvertebrates is a 2, indicating moderate concern.

Weighted Condition Score
The *Weighted Condition Score* (WCS) for BICA water quality is 0.333 indicating an overall good condition with a stable trend. However, this score is at the very top of the good condition

range, bordering on moderate condition. If just one of the selected measures were to decline, water quality could become a component of higher concern.

Water Quality

Measures	SL	CL
Dissolved oxygen	3	0
E. coli	3	2
pH	3	0
Water temperature	3	1
Presence of pesticides	1	n/a
Macroinvertebrates	3	2

WCS = 0.333

Sources of Expertise

Jeff Arnold, NPS Aquatic Ecologist, Yellowstone Center for Resources
Cathie Jean, GRYN Management Assistant

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4.14 Viewscape

Description

A viewshed is the area that is visible from a particular location or set of locations, often developed using GIS analysis tools. Two datasets are required to calculate a viewshed using GIS: a digital elevation model (DEM) and point or polyline data defining points in which a person would be viewing a landscape. With the defined data, GIS software determines visibility to and from a particular cell or set of cells in a DEM resulting in a viewshed layer. This viewshed layer is a raster that defines the visible area on the landscape from the point or set of points contained within an outline of a polygon. Combining viewshed layers with layers that indentify areas of undesirable impacts on the landscape creates a quantitative description of visual stress on a viewshed; repeating this process for multiple viewshed layers in a pre-defined landscape, such as a National Park, provides a quantitative description of stress across the viewscape in the area.

Multiple studies indicate that people prefer natural compared to developed landscapes (Sheppard and Sheppard 2001, Kearney et al. 2008, Han 2010). The National Park Service Organic Act (16 U.S.C. l) implies the need to protect the viewscapes of National Parks, Monuments, and Reservations. Specifically, the enabling legislation for BICA states the park's should "provide for the public outdoor recreation use and enjoyment of Yellowtail Reservoir and lands adjacent thereto in the States of Wyoming and Montana by the people of the United States and for the preservation of the scenic, scientific and historic features contributing to public enjoyment of such lands and waters" (Public Law 89-664). However, defining a desirable viewscape is widely regarded as a subjective and difficult process, because what is preferable is intrinsically humanistic and varies by individual. In BICA, development is minimal compared to many areas in the conterminous United States, yet some non-natural features still exist. Many of these non-natural features, such as roads, boat landings, and parking areas enable recreational access to the park's resources, which is a primary purpose for the park (Public Law 89-664). Therefore, this assessment relied on input from park and GRYN staff to determine desirable and undesirable features within the park's viewscape.

Measures

- Development such as roads and power-lines
- Housing density visible from observation points
- Land ownership visible from observation points

Reference Conditions/Values

Reference condition for the park's viewscape is undefined. This is the first formal viewscape assessment for BICA and may be useful for defining reference condition in future assessments. However, the park's enabling legislation mandates the "preservation of scenic, scientific and historic features" (Public Law 89-664); this should be considered when assessing visual resources in the park.

Data and Methods

Park and GRYN staff identified seven priority observation points within the park for this analysis: Four Winds Overlook, Ok-A-Beh Marina, Lockhart Ranch, Devil Canyon Overlook, Mustang Flats, Sullivan's Knob, and Stateline (Plate 16). Visitors frequently observe the landscape in the park from the defined observation points. At each of these points, a viewshed was calculated using ESRI's Spatial Analyst Viewshed Tool in ArcGIS 10.0, which requires point or polyline GIS data (representing the viewing location) and a DEM. For each of the observation points, a point shapefile was created for use with the Viewshed tool and the DEM used for each observation point was mosaicked from National Elevation Dataset (NED), which has a resolution of approximately 10 m. A 1.7-m (5.5-ft) offset was applied to each observation point shapefile to account for average human height. The result of the operation is a theoretical viewshed layer that represents the visible area from a point without correcting for visibility factors (e.g, vegetation, smoke, humidity, heat shimmer, or curvature of the earth).

NPS staff acquired current (summer 2011) ground condition photos at four of the observation points to supplement GIS data. Four photos, oriented towards cardinal directions, were acquired at the each observation point. The photos provide an illustration of typical views at each location. However, they are not useful in providing quantifiable information for the viewscape of the park.

Methods for development of GIS viewshed layers used by Melanie Myers (NPS Contractor, GIS Analyst) are provided in Appendix G.

Current Condition and Trend

General Viewshed

The composite visible area from all observation points, hereafter, composite viewshed, is 1,159 km^2 (Plate 16). The Pryor and Bighorn Mountains restrict the distance visible to the west and east, from most observation points, respectively. The Four Winds, Devil Canyon Overlook, and Stateline observation points contribute much of the area visible within the composite viewshed to the north and south of the park. Within the composite viewshed, the primary anthropogenic features include the power lines that travel north to south through the park and roads within the park. Other manufactured objects exist within the park, such as pavilions, interpretive signs, and restrooms.

Development Features

Roads or power lines are visible from all observation points examined (Plate 17). However, natural landscapes dominate the visible area from all observation points (Photo 20Photo **23**). Even though visibility of development features at observation points is minimal, when visitors travel through the park various development features are visible. The primary park road in the southern portion of the park traverses south to north from the Lovell entrance to the park's interior, approximately parallel to a visible power line. In addition, when travelling on the road through the PMWHR, the fence for the horse range is visible on occasion. Other development features in the park are historical and provide interpretive value to visitors, such as the Mason-Lovell Ranch and the Lockhart Ranch (Photo 24).

Photo 20. View from Mustang Flats observation point, looking north (NPS photo).

Photo 21. View from Stateline observation point, looking east (NPS photo).

Photo 22. View from Sullivan's Knob observation point, looking south (NPS photo).

Photo 23. View from Devil Canyon Overlook observation point, looking north (NPS photo).

Photo 24. Corral at the Lockhart Ranch (SMUMN GSS).

<u>Land Ownership</u>

Related to development features is land ownership, as differences in land ownership can imply different likelihoods of development in the future. The viewsheds for all observation points examined in this assessment are primarily composed of Federal, undeveloped land (Table 42, USGS 2011). However, this land could undergo development in the future and therefore is important to monitor. The Bureau of Indian Affairs (BIA) owns the majority of land within the composite viewshed (62%) and BLM owns the next largest portion (12%). NPS owns a small percentage of the land visible from the observation points (7%). Land owned by individual private landowners is minimal within the composite viewshed. According to the data used in this assessment, no individually owned private land is visible from the observation points. However, the data used in this analysis did not define 7% of the composite viewshed (82 km^2); this area could include some private land. The composite viewshed layer also identified small proportions of land owned by other federal and state agencies.

Table 42. BICA Land ownership within the composite viewshed from identified observation points (USGS 2011).

Land Owner Name	Area (km^2)	% Viewshed
Bureau of Indian Affairs (BIA)	720	62%
Bureau of Land Management (BLM)	143	12%
National Park Service (NPS)	87	7%
Undefined	82	7%
Bureau of Reclamation (BOR)	52	5%
Forest Service (USFS)	51	4%
State Land Board	17	1%
State Fish and Wildlife	6	1%

Housing Density

Housing density is low for most of the area within the composite viewshed. USGS (2011) data describe 74% of the area within the composite viewshed. Over 60% of the visible area from the observation points is undeveloped or contains less than 1.5 housing units/km^2 (Table 44). The composition of the 26% of the composite viewshed that is not defined by USGS (2011) consists of many private parcels (M. Myers, pers. comm., 2012). Visual inspection of housing density change data indicates that housing density is not anticipated to change noticeably through 2030 (M. Myers, pers. comm., 2012).

Table 43. BICA housing density within the composite viewshed from identified observation points (USGS 2011).

Housing Density	Area (km^2)	% Area
Private undeveloped	664	57%
<1.5 units/km^2	104	9%
1.5-3 units/km^2	44	4%
4-6 units/km^2	21	2%
7-12 units/km^2	10	1%
13-24 units/km^2	6	1%
25-49 units/km^2	2	<1%
50-145 units/km^2	<1	<1%
146-494 units/km^2	<1	<1%
495-1,234 units/km^2	<1	<1%
1,235-2,470 units/km^2	<1	<1%
>2,470 units/km^2	<1	<1%
Commercial/industrial	<1	<1%
Undefined	305	26%

Threats and Stressor Factors

Development of the areas adjacent to the park is the primary threat to the viewscape at BICA. The fact that many of the views identified in this viewshed analysis throughout the park include non-NPS land makes development prevention a difficult task. Monitoring potential development opportunities into the future should be a priority for park management.

Data Needs/Gaps

While this assessment provides some baseline information regarding the park's visual resources, it should not be considered all-inclusive. Incorporation of different and new GIS data sets, such as a higher resolution DEM, additional non-natural feature layers, or land ownership data with more coverage would enhance a future analysis. In addition, continued monitoring of observation points through on-the-ground photography is a low-cost task that can help document changes in visual resources over time.

Overall Condition

Significance Level was not determined by the project team for the measures of this component. *Weighted Condition Score* is determined with all components having a *Significance Level* of 2, indicating moderate importance for defining the overall condition of BICA viewscapes.

Development Features

The natural landscape at BICA is the primary visible feature at all observation points examined in this assessment. Most development features within park (i.e., roads, boat ramps, historic ranches) are acceptable according to mandates from the park's enabling legislation. However, some features, such as the power line running adjacent to the primary park road, impair some of the natural viewscape within the park. Therefore, the *Condition Level* for this measure is 1, or of low concern.

Land Ownership

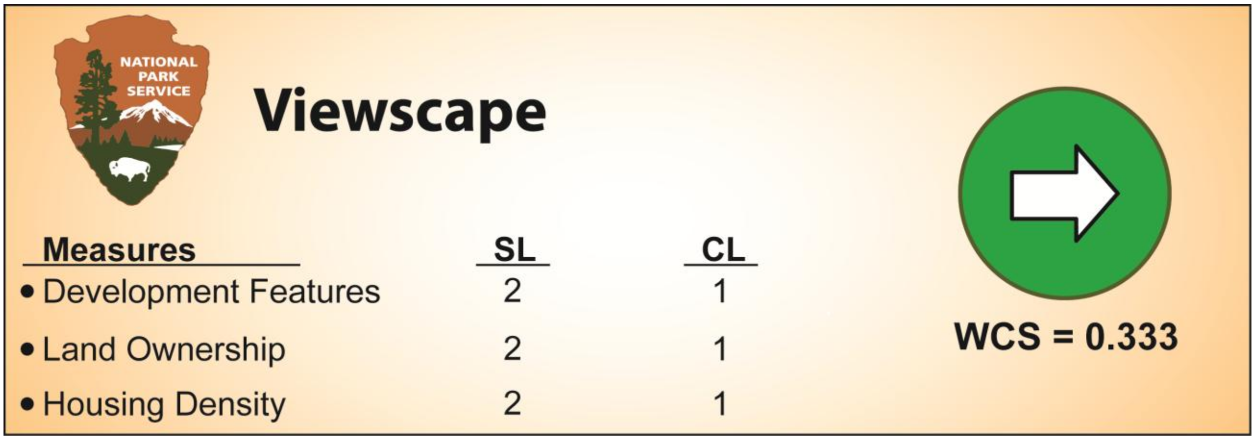
Federal agencies manage most of the visible area from the observation points defined in this assessment, which should translate to limited developable area. However, NPS owns a small portion of all the federal land within the composite viewshed and therefore does not have exclusive control over future management actions that could alter the park's viewscape. The *Condition Level* for this measure is 1, indicating low concern.

Housing Density

Analysis of housing density data within the composite viewshed shows that most of the land visible has limited to no housing development. However, housing developments in Fort Smith and Lovell are more obvious from certain parts of the park not included in the observation points. Therefore, the *Condition Level* of this measure is 1, indicating low concern.

Weighted Condition Score

The *Weighted Condition Score* for this component is 0.333, indicating condition is of low concern; all measures were scored with a *Condition Level* of 1.



Sources of Expertise

Melanie Myers, NPS Partner Colorado State University, I&M GIS analyst

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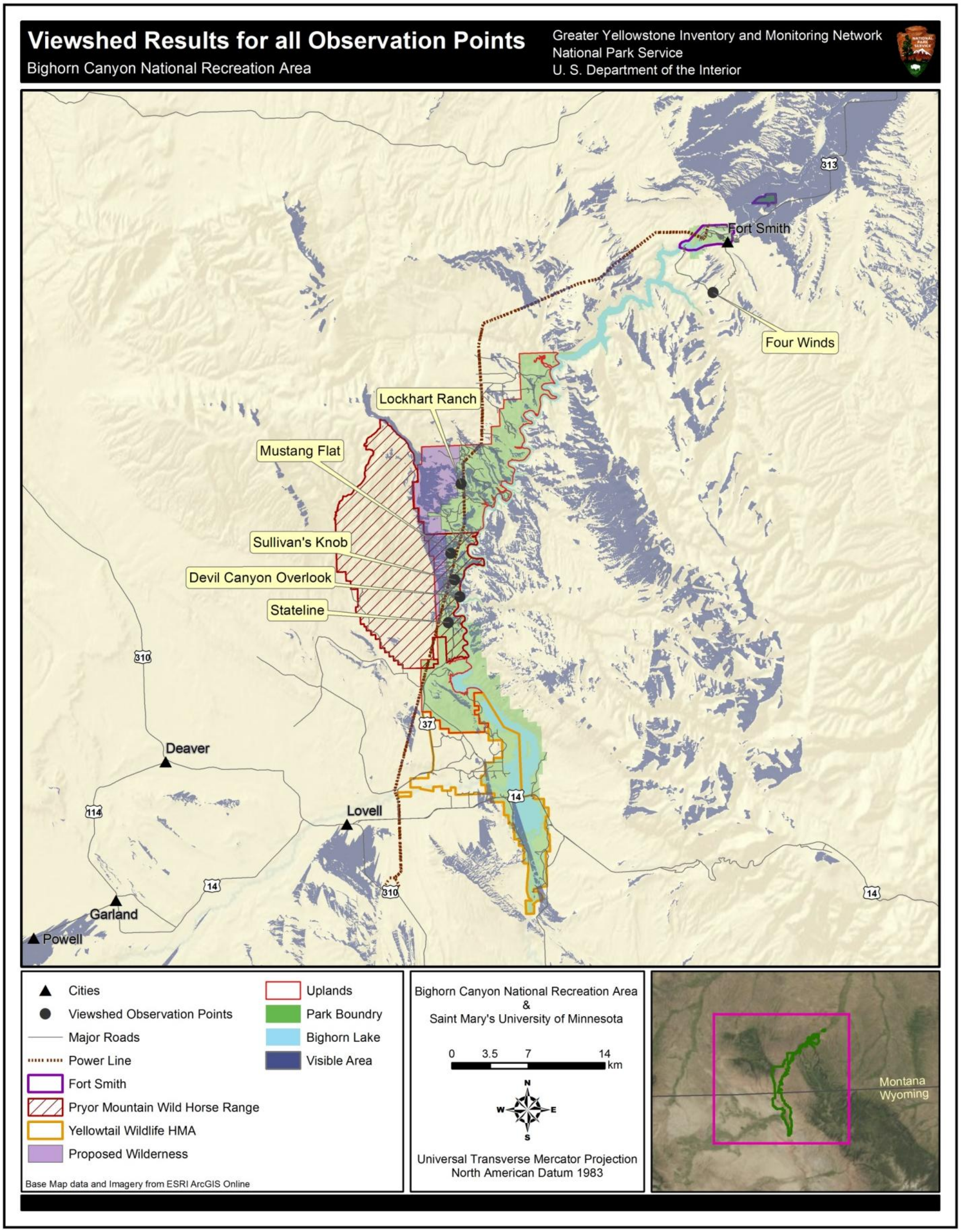

Plate 16. Composite viewshed for all observation points and park management boundaries.

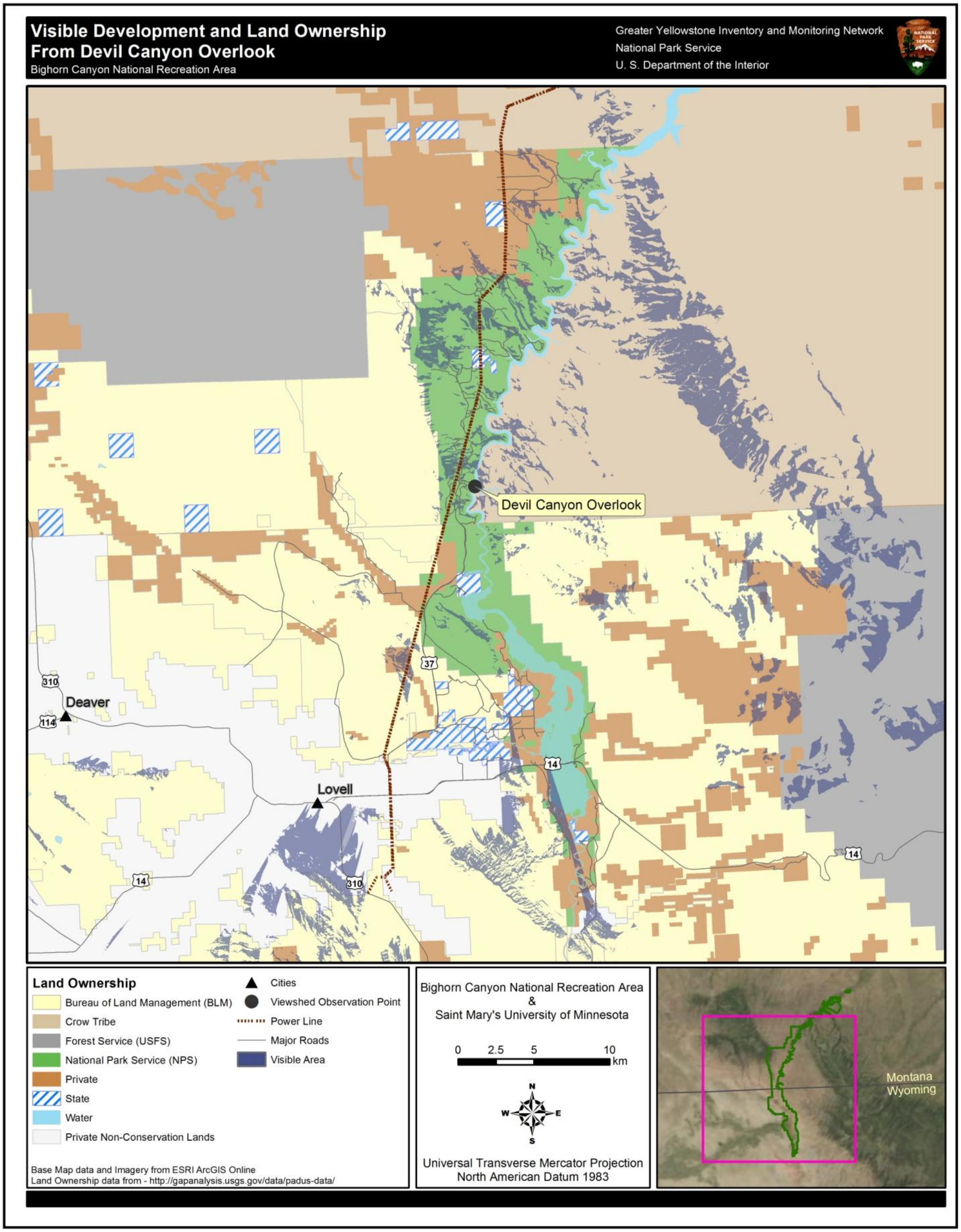

Plate 17. Devil Canyon overlook viewshed and land ownership.

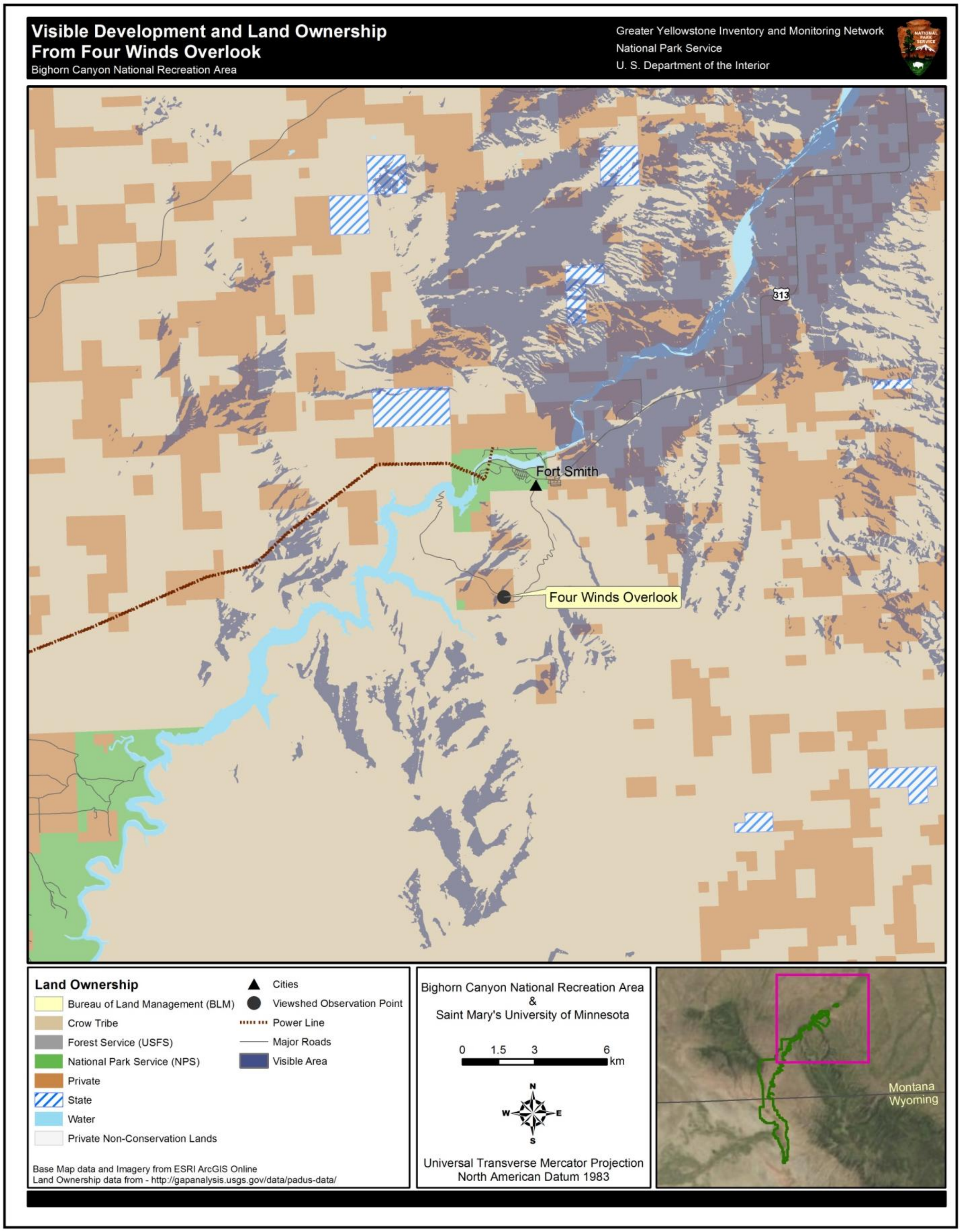

Plate 18. Four Winds overlook viewshed and land ownership.

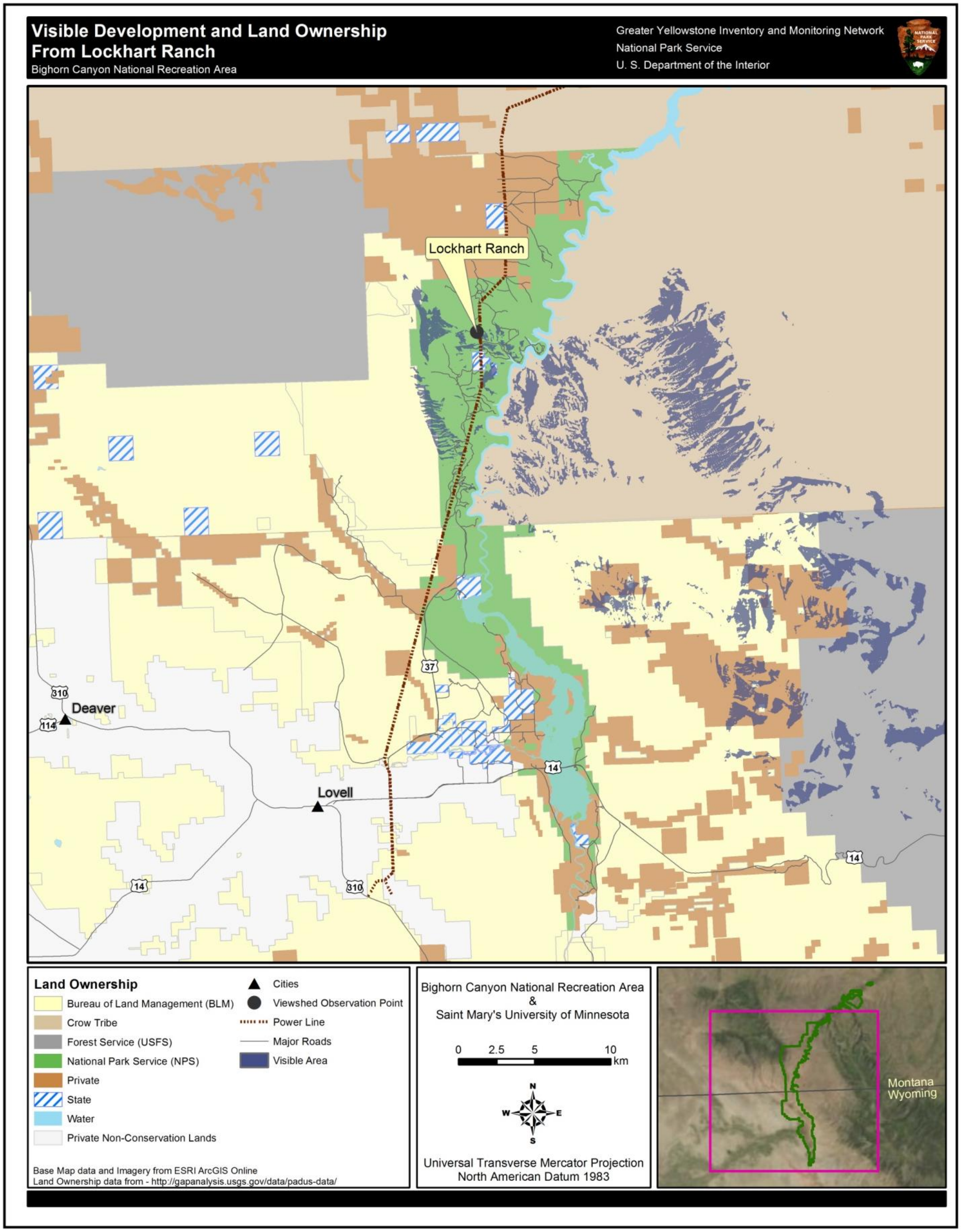

Plate 19. Lockhart Ranch viewshed, development, and land ownership.

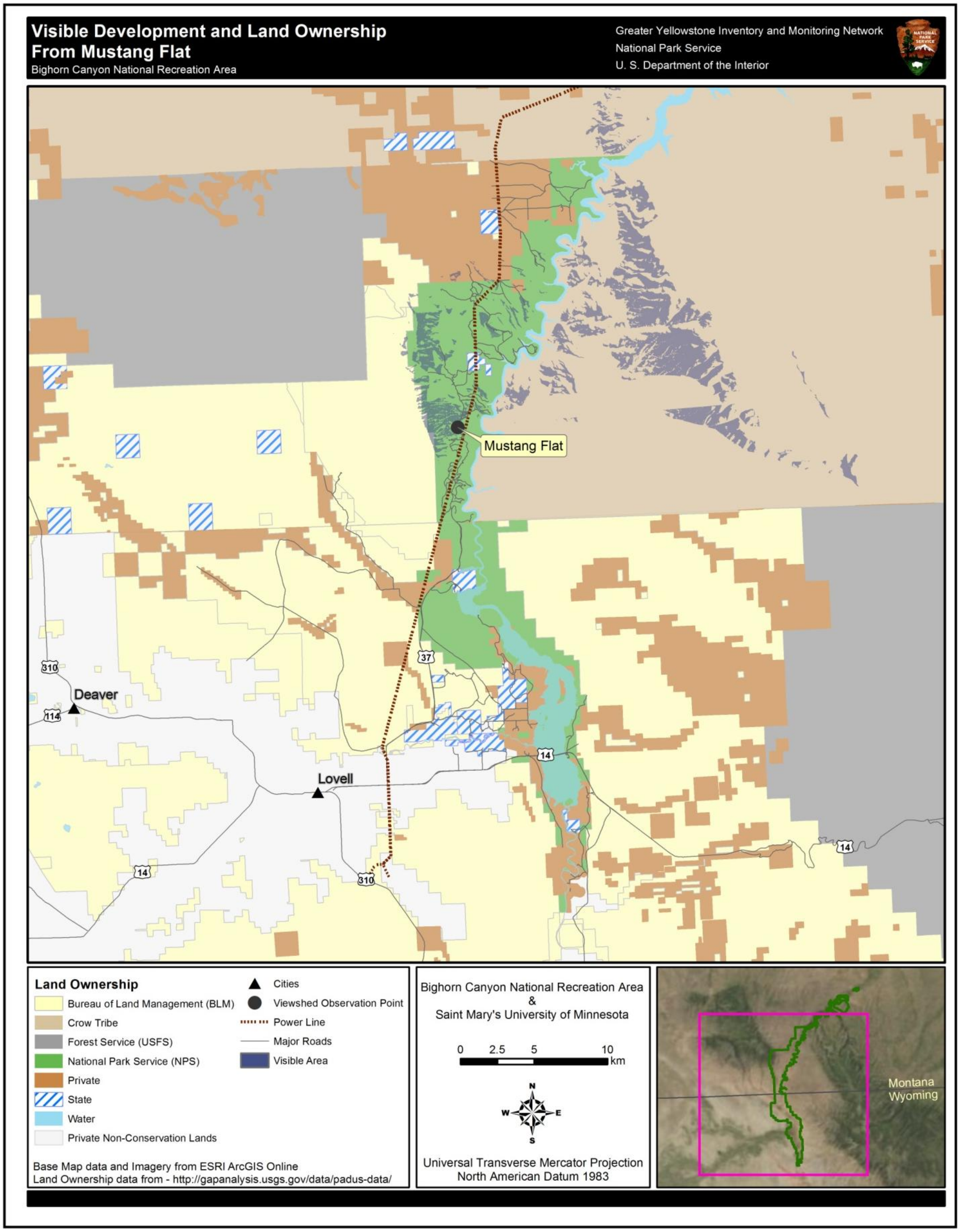

Plate 20. Mustang Flat viewshed, development, and land ownership.

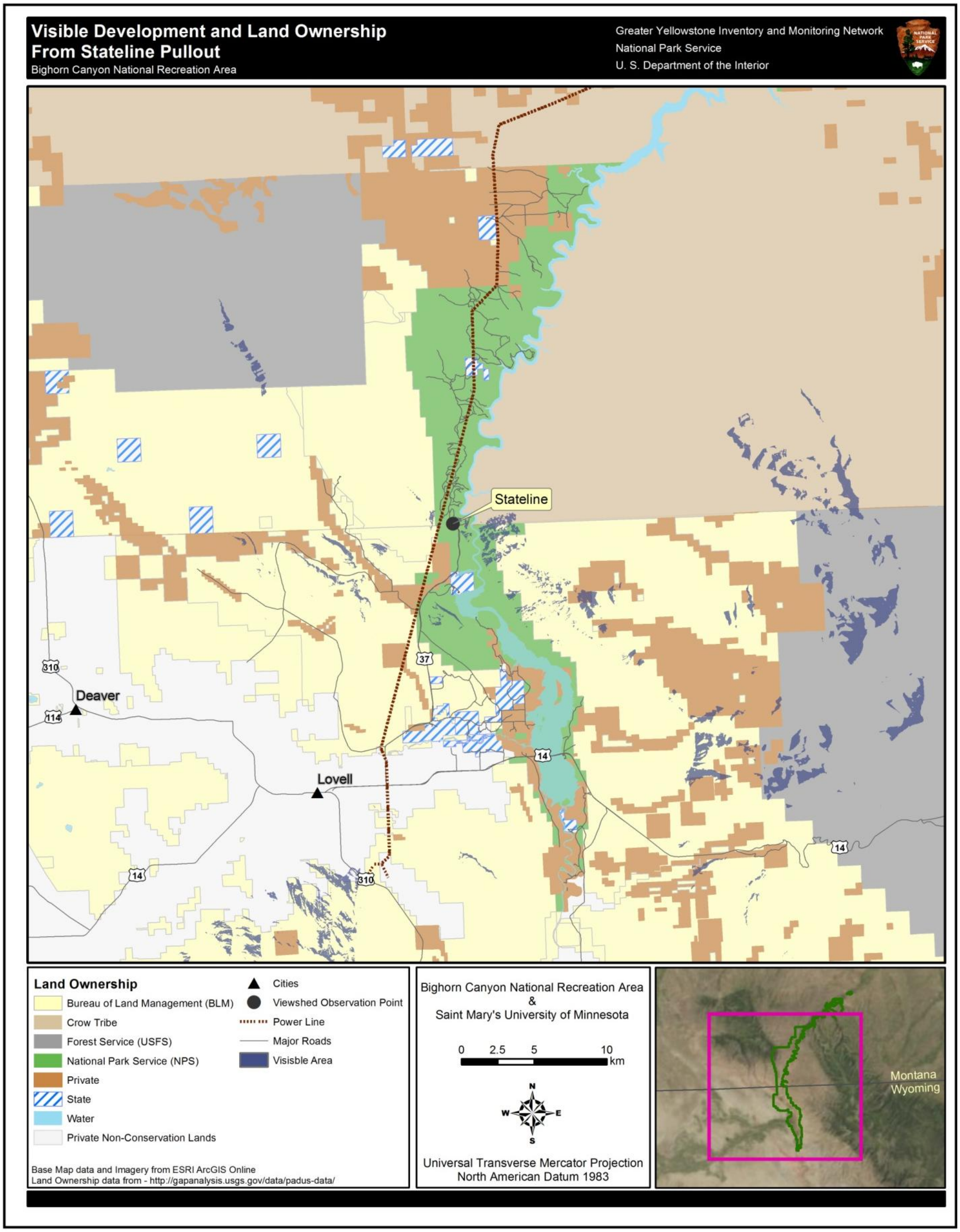

Plate 21. Stateline pullout viewshed, development, and land ownership.

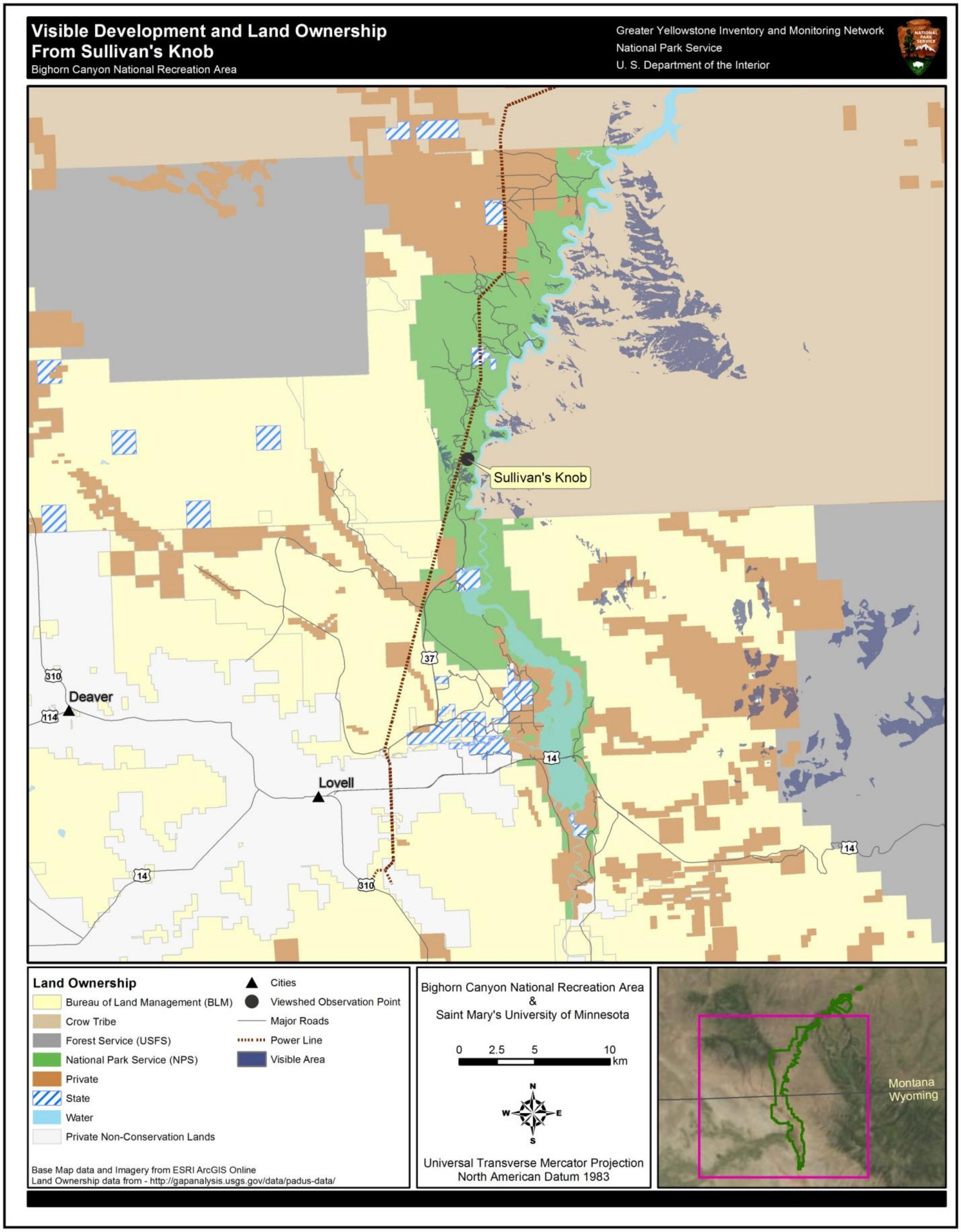

Plate 22. Sullivan's Knob viewshed, development, and land ownership.

4.15 Seeps and Springs

Description

There are 28 confirmed springs within BICA (Sessoms et al. 2009). The GRYN identified arid land seeps and springs as a Vital Sign (Jean et al. 2005). Springs and seeps represent an important source of water for wildlife within the park's semi-arid environment (Jacobs et al. 1996). These seasonal and perennial water sources support a variety of wetland and riparian habitats (Schmitz 2009). Riparian areas around seeps and springs can provide habitat for 75% of the species present in arid regions (Shepard 1993, as cited by Stagliano 2008). In BICA, aquatic macroinvertebrates make up a substantial proportion of total biodiversity within the springs' waters (Stagliano 2008). Springs and seeps also strongly influence nearby vegetation communities, creating rich microhabitats within the arid landscape (Stevens et al. 2004). Additionally, some measures used to assess the condition of seeps and springs in this assessment are GRYN Vital Signs, including groundwater quality and benthic macroinvertebrates (Simmons et al. 2004, Jean et al. 2005). Water quality parameters considered in this assessment include pH, dissolved oxygen (DO), and water temperature. Discharge is another measure of spring and seep condition, and is a primary driver of spring ecosystem diversity; macroinvertebrate diversity and richness are positively related to spring discharge in BICA (Stagliano 2008).

Photo 25. Layout Spring (Denine Schmitz 2009).

Measures

- Discharge
- Changes in pH, dissolved oxygen, water temperature
- Macroinvertebrates
- Extent of area influenced by springs

Reference Conditions/Values

Pristine springs were defined as the reference condition for macroinvertebrate communities in BICA by Stagliano (2008). Water quality parameters are measured against EPA aquatic life standards and Montana and Wyoming state water quality standards.

Data and Methods

Stagliano (2008) collected macroinvertebrate and associated habitat data from 21 BICA seeps and springs in 2007.

Water temperature, pH, DO, and discharge data were extracted from the STORET database for BICA between 2006 and 2010 and used for this assessment. All STORET entries without numeric values were removed (EPA 2011). Discharge values recorded in liters per second were converted to cubic feet per second (cfs). Mean values for each parameter were calculated for springs with five or more samples by SMUMN GSS staff.

National Agricultural Imagery Program (NAIP) data were used to examine the influence seeps and springs have on surrounding vegetation communities.

Schmitz (2009) surveyed 26 microhabitats surrounding ten springs in BICA which included a variety of species, microhabitats, geomorphic settings, and geologic substrates.

Current Condition and Trend

Discharge

Discharge has been measured at several BICA springs; those springs with five or more samples are analyzed here. Table 44 displays the average discharge of these springs as measured between 2006 and 2010 (EPA 2011). Layout Spring has a significantly higher mean discharge than the other four springs. It is important to note that discharge was measured throughout the year and may vary due to variations in weather conditions (e.g., periods of drought or higher than average precipitation). Base level discharge (measurements taken in the fall) would provide a better characterization of spring flow (Schmitz, pers. comm., 2011).

Table 44. Average discharge of five BICA springs, 2006-2010 (EPA 2011).

Spring	Average Discharge (cfs)	No. of Samples
North Davis Spring	0.0011	10
Lockhart Stockpond Spring	0.0021	5
Lockhart South Spring	0.0018	5
Layout Spring	2.61	22
Hillsboro Main Spring	0.24	12

Depth to the water table is an important consideration for spring discharge. However, no data are currently available for springs and seeps in BICA. Spring discharge is typically reduced where the water table is deeper (USGS 2011).

Change in pH, Dissolved Oxygen, and Water Temperature

The EPA and the states of Wyoming and Montana have established water quality standards for pH and water temperature, while DO standards vary based on fish species and life stage (Table 45).

Table 45. EPA, Wyoming, and Montana water quality standards for pH, DO, and water temperature (Sigler 2011).

Water Quality Parameter	EPA	Wyoming	Montana
pH	6.5 - 9.0	6.5 - 9.0	6.5 -8.5
DO	Varies with fish species and life stage	Varies with fish species and life stage	Varies with fish species and life stage
Water temperature	-	30° C max Normal + 2.2	0-26.6° C Normal + 0.28 Normal – 1.1

Sessoms et al. (2009) sampled 20 of the 28 known springs in BICA to establish baseline water quality data. Thirteen springs are considered sensitive to changes in pH caused by nutrients, organic material, and acid deposition (Schmitz 2006). North Davis Spring had a significantly lower mean DO than the other springs, while Layout Spring had a significantly lower average temperature than other springs. pH and temperature means were well within EPA and state water quality standards. There is not enough long-term water quality data to determine potential change in parameters of interest over time or establish a trend.

Table 46 displays mean pH, DO, and water temperature for the six seeps and springs in BICA with five or more samples per parameter. Mean pH measurements were close to neutral (7.0) for all six springs.

Table 46. Mean pH, DO, and water temperature of springs in BICA. Data obtained from the STORET database, 2006-2010 (EPA 2011).

Spring	pH	DO (mg/L)	Temperature (°C)
Headgate Seep	7.33	7.28	11.94
Hillsboro Main Spring	7.32	8.27	10.46
Layout Spring	7.68	10.3	5.27
Lockhart South Spring	6.92	8.41	10.04
Lockhart Stockpond spring	7.1	8.04	9.42
North Davis Spring	6.93	3.99	9.19

<u>Macroinvertebrates</u>

Stagliano (2008) identified 146 macroinvertebrate taxa in 26 samples from 21 springs in BICA. Seventeen taxa were identified as indicators of good to excellent spring health (Table 47). Layout Spring was the most diverse site sampled with 33 taxa documented (Stagliano 2008). Medium-high volume wall springs were the most diverse type of spring for macroinvertebrates in the park. No threatened or endangered macroinvertebrate species were encountered during sampling (Stagliano 2008). To assess the biological integrity of springs, the author used the state's water quality standard metrics (MTDEQ 2006).

Table 47. Macroinvertebrate indicator taxa present in BICA springs (**+** denotes significant indicator, **++** denotes highly significant indicator) (Stagliano 2008).

Indicator Taxon	BICA Spring Significance
Stoneflies	
Amphinemura banksi	++
Hesperoperla pacifica	++
Mayfly	
Baetis tricaudatus	++
Caddisflies	
Hesperophylax cf. designatus	+
Lepidostoma unicolor	++
Beetles	
Optioservus	++
Heterlimnius corpulentus	++
Hydroporus	+
Diptera (true flies)	
Brillia	++
Caloparyphus	+
Dicranota	+
Dixa	+
Euparyphus	+
Ormosia	+
Parametriocnemus	++
Tvetenia bavarica Gr.	++
Tipula	+

The Montana Department of Environmental Quality (MDEQ) impairment threshold for spring streams categorized as Low Mountain/Valley (majority ecotype in BICA) is a score of <48 on a multimetric macroinvertebrate index (MMI) (MDEQ 2006). Higher MMI scores indicate healthier macroinvertebrate communities. Spring macroinvertebrate communities in BICA were assessed using this method. Sites with the highest MMI scores included: Bear Run Spring, Cass Spring, Cattrack, Headgate Seep, Hillsboro Main and Side Springs, Layout Springs (both), Trail Creek Campground Main and #2 Springs (Stagliano 2008). Springs were also assessed for habitat quality, with six sites ranked as good-excellent, eight sites had fair habitat quality, five sites were slightly impaired, and two sites were moderately to severely impaired (Stagliano 2008).

Macroinvertebrate MMI ratings were not always indicative of the overall health of seeps and springs. For example, Mason-Lovell Spring was considered impaired because it was impacted by silting and had a low number of macroinvertebrates species, but it received a high MMI score (Stagliano 2008). In contrast, Hidden Spring was considered to be in good ecological health with high macroinvertebrate taxa diversity, but received a lower MMI score (Stagliano 2008). These contradictory results are due to the fact that the MMI was developed for stream ecosystems and does not factor in all of the BICA indicator species, which are better measures of spring health

(Stagliano, pers. comm., 2011). Table 48 displays ranking of springs based on ecological condition and biological integrity. Springs were ranked against other springs of the same category, from highest to lowest biological integrity.

Table 48. Spring and seep rankings based on aquatic ecological system condition and biological integrity, by spring class type (Stagliano 2008).

Med-High Volume Wall Springs (MVWS)	Low Volume Wall Springs (LVWS)	Single Thread Channel Springs (STCS)	Wetland/Ponded Springs (WPSS)
1. Layout Creek	1. Pickett's Wall Spring	1. Cass	1. Headgate Seep
2. Trail Creek Campground Main	2. Trail Creek Campground #2	2. Finley	2. Bear
3. Hillsboro Main Spring	3. Hillsboro Side Spring	3. Rick's	3. Pentagon
		4. Lockhart	4. Sorenson Spring Pond
		5. Hidden	5. Mason-Lovell Spring
		6. Cattrack	6. Lockhart Pond Spring
		7. Sorenson	
		8. Tyler's Torrent	
		9. Lockhart South	
		10. Lockhart Springhouse	
		11. North Davis Spring	

Extent of Area Influenced by Springs

Arid land springs and seeps have an ecological impact disproportionate to their spatial extent in the park (Sigler 2011). The extent of spring ecosystems is driven by discharge, water quality, and flow dynamics (Schmitz et al. 2007). Fluvial processes were found to be the primary drivers of plant associations around BICA springs (Schmitz 2009). BICA springs appear to have associated vegetation surrounding most sites in the park based on NAIP imagery. Plate 23 displays known/reported spring locations within BICA. Plate 24 displays the location of Headgate Seep and color infrared aerial imagery to highlight vegetation surrounding the seep.

Schmitz (2009) identified six plant associations and three microhabitat types around sampled springs. The six plant associations were, *Symphoricarpos occidentalis/Maianthemum stellatum*, *Juncus parryi/Carex atrata*, *Typha latifolia/Berula erecta*, *Sullivantia hapemannii*, *Carex pellita/Luzula parviflora*, and *Salix amygdaloides/Phragmites australis* (Schmitz 2009). A total of 102 plant species were identified during the study (Appendix H).

Hapeman's coolwort (*Sullivantia hapemanii* var. *hapemanii*) is a rare plant that occurs primarily around seeps and springs in BICA (Heidel and Fertig 2000). The plant has a heritage rank of S2 in Montana, which means the species is at risk due to very limited and/or potentially declining populations, range, or habitat (Heidel and Fertig 2000, MTNHP 2011). The state of Wyoming ranks Hapeman's coolwort as S3, which denotes a medium conservation priority (Heidel and Fertig 2000).

Threats and Stressor Factors

Park staff identified climate change, water diversions, damming, and groundwater pumping as threats to BICA seeps and springs. All these activities alter natural water availability and discharge levels. Groundwater withdrawals reduce pressure within aquifers, causing water levels to drop and eventually reduce spring discharge (USGS 2011). Macroinvertebrate diversity and abundance are negatively correlated with spring diversions and cattle access to springs in BICA (Stagliano 2008). Two nearby ranches divert water near BICA (Schmitz, pers. comm., 2011). Proper water diversions (those that originate below the spring run out) would have few negative impacts on spring ecosystems (Schmitz, pers. comm., 2011). BICA diverts water from some streams as well, but only below run out (Bromley, pers. comm., 2012).

Data Needs/Gaps

Depth to groundwater table was identified as an important aspect of seep and spring discharge; however, no groundwater table depth data is available for BICA before 2011. Ground water table depth information will be a valuable addition to spring discharge data. Additionally, data related to water diversions and ranching near BICA would help to characterize the threat to springs and seeps; this is of particular importance regarding the spring at the Mason-Lovell Ranch.

Further water quality data should be collected to identify changes and long-term trends in pH, DO, and water temperature.

Further surveys of macroinvertebrate communities in BICA seeps and springs would allow measurement of change from 2007 baseline data. Stagliano (2008) stated that intensive sampling could potentially double the documented taxa in BICA springs and seeps.

Schmitz (2009) suggested a full vegetation survey of BICA springs to identify additional plant species and to develop a spring vegetation monitoring protocol. This could help better quantify the extent of spring influence on plant communities as well.

Overall Condition

Discharge

During initial scoping meetings, the project team assigned the measure of discharge a *Significance Level* of 3. Limited data exist on spring and seep discharge in BICA between 2006 and 2010. A *Condition Level* for discharge cannot be assigned at this time.

Changes in pH, Dissolved Oxygen, and Water Temperature

A *Significance Level* of 2 was assigned to the measure of changes in pH, dissolved oxygen, and water temperature. Several BICA seeps and springs have been monitored for these water quality parameters. All three water quality parameters meet EPA and state water quality standards. The *Condition Level* for this measure is a 0.

Macroinvertebrates

A *Significance Level* of 2 was assigned to the measure of macroinvertebrates. Stagliano (2008) collected baseline data on macroinvertebrate communities present in BICA springs and defined macroinvertebrate taxa indicators of reference condition; however, additional information from future studies is necessary to determine a *Condition Level* for this measure.

Extent of Area Influenced by Springs

A *Significance Level* of 3 was assigned to the measure extent of area influenced by springs. It is difficult to quantify exactly how large an area is influenced by each spring in BICA; however, it is clear from visual observation of NAIP imagery that areas of vegetation commonly surround seeps and springs in the park. Distinguishing where spring ecosystems end and a wetland, pond, or creek ecosystem begins can be difficult. Schmitz (2009) identified major plant associations around a subset of BICA springs. However, there is not enough information on the measure to designate a *Condition Level.*

Weighted Condition Score

A *Weighted Condition Score* (WCS) cannot be assigned for seeps and springs in BICA due to lack of data on component measures.

Seeps and Springs

Measures	SL	CL
• Discharge	3	n/a
• Extent of area influenced by springs	3	n/a
• Change in pH, DO, water temperature	2	0
• Macroinvertebrates	2	n/a

WCS = N/A

Sources of Expertise

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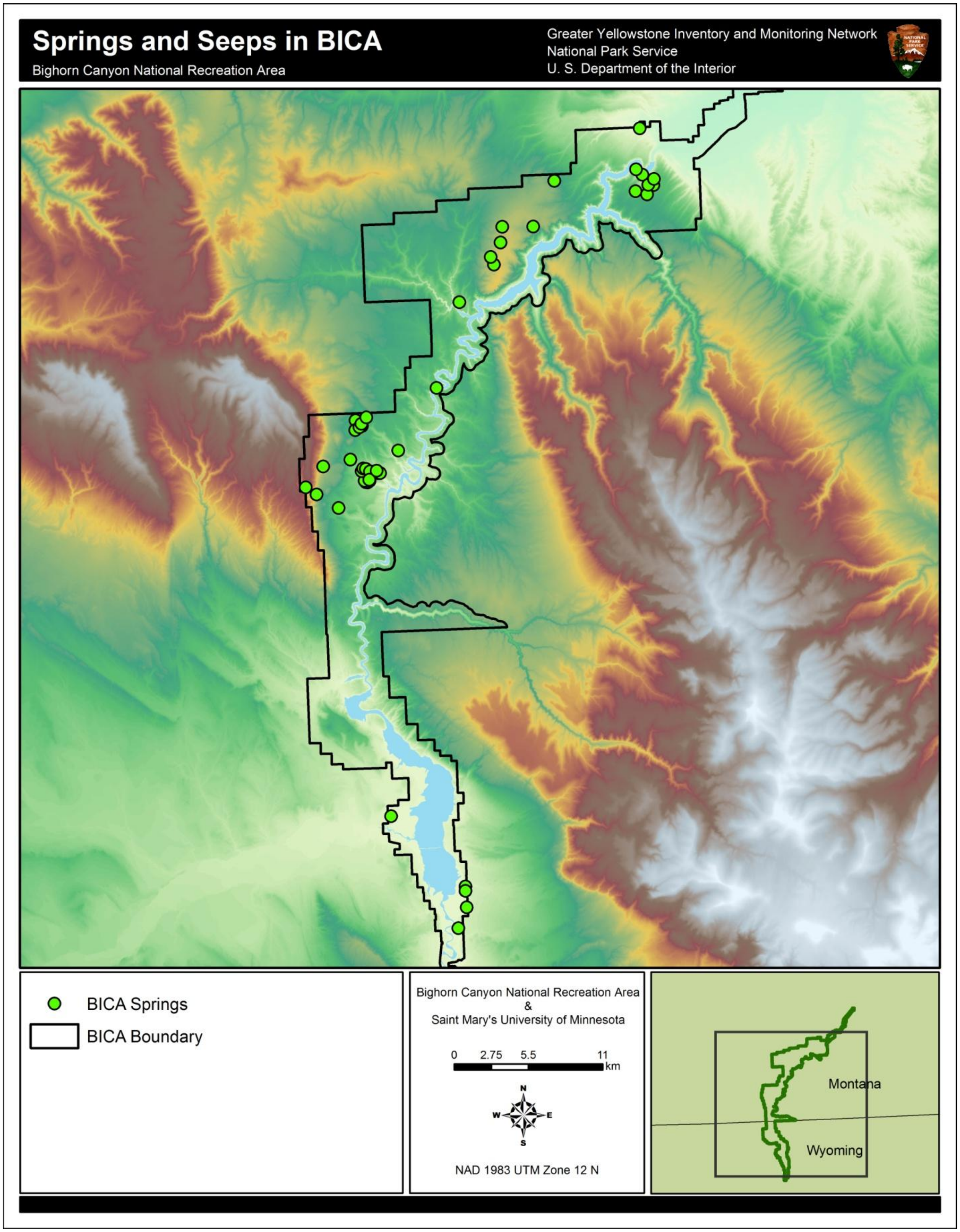


Plate 23. Location of documented springs in BICA.

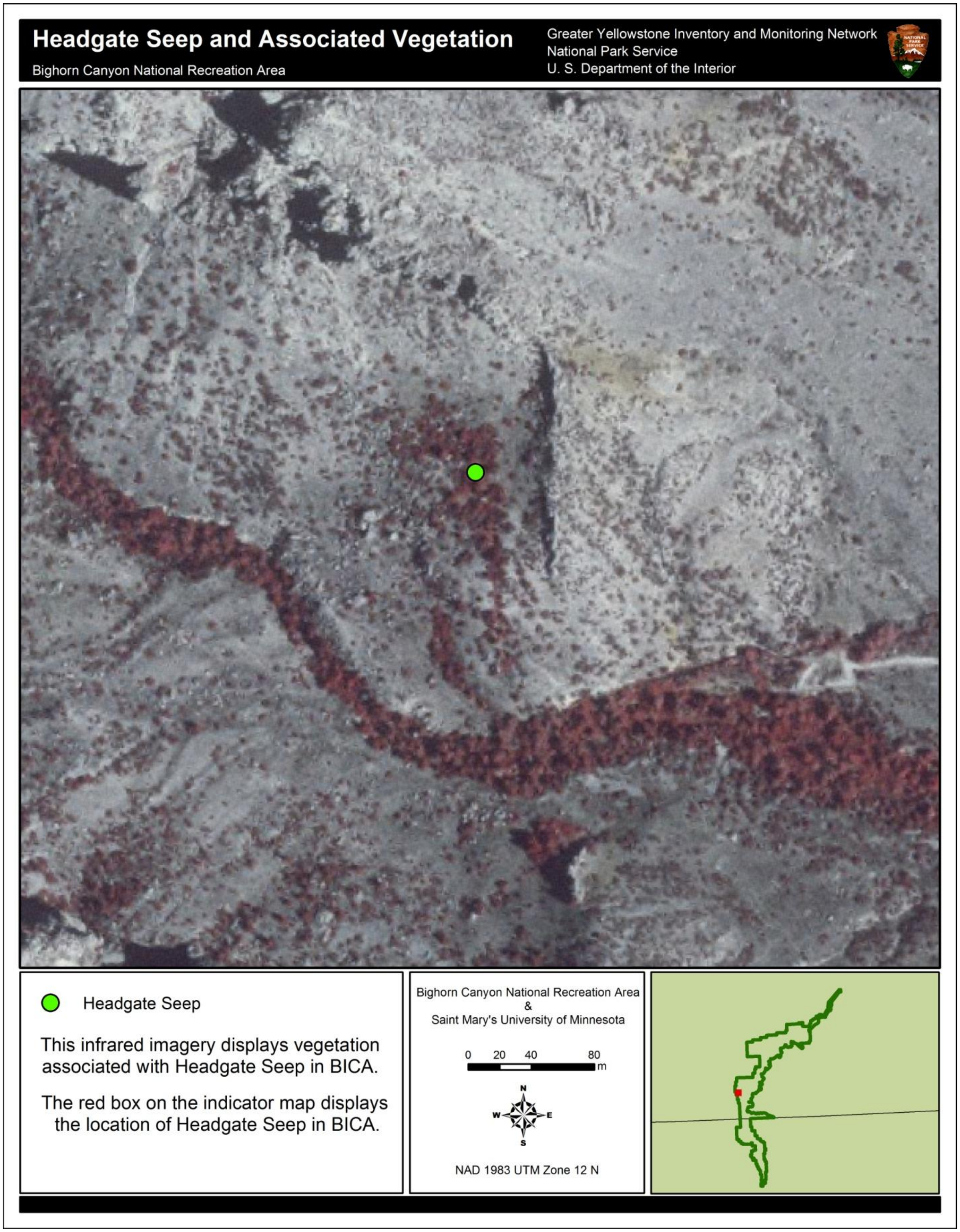


Plate 24. Headgate seep in BICA is displayed with color infrared imagery to highlight the associated vegetation.

4.16 Erosion

Description

The natural process of erosion has shaped the canyons and cliffs of many areas, including BICA. However, accelerated erosion due to human disturbance, overgrazing, or natural disturbances such as fire and flooding has become a serious concern in many natural areas. Soil erosion is a particular concern in arid and semiarid regions such as BICA where most biological processes occur in the upper 10-20 cm of soil (Evenari 1981, as cited by Crowe 2007). Soil loss disrupts hydrological processes and soil biota, which inhibits nutrient cycling and plant establishment, contributing to further erosion (Crowe 2007). According to its 2001 Management Policies, the NPS strives "to understand and preserve the soil resources of the park units and prevent, to the extent possible, unnatural erosion, physical removal or contamination of the soil or its contamination of other resources" (NPS 2000, as cited by NPS 2004). Additionally, one of BICA's management objectives is to "mitigate, when possible, the effects of erosion and sedimentation on park facilities and resources" (Jacobs et al. 1996, p. 6).

Several characteristics of the BICA landscape make it susceptible to erosion, including its arid climate, sparse vegetation, erodible quality of the bedrock (especially shale), and steep slopes (USACE 2010, as cited by KellerLynn 2011). A 2004 assessment of rangeland health in the Pryor Mountain Wild Horse Range (PMWHR), which includes a portion of BICA, estimated that 57% of the landscape was impacted by severe erosion (Ricketts et al. 2004). Within the BICA study unit, severe erosion was observed along 31% of sampling transects. Evidence of erosion included rilling, plant pedestaling, and erosion pavements. Plant pedestalling occurs when erosion removes the soil around a plant, leaving it on a pillar above the ground surface. In BICA, pedestals up to 0.6 m (2 ft) were observed (Ricketts et al. 2004). Erosion pavements form when fine surface soils are removed by wind or water, leaving gravel and stone behind. As a result these pavements appear "very cobbly and bouldery with little soil" (Ricketts et al. 2004, p. 26).

Mass wasting, the downslope movement of soil and rock, also occurs in BICA in the form of landslides, rockfalls, and slumps (KellerLynn 2011). The possibility of landslides and rockfalls are a threat to visitor safety in the recreational area and have led to use restrictions in certain areas of BICA, most notably Bull Elk Basin (KellerLynn 2011). Mass wasting can be triggered by seismic activity, heavy rains and runoff, high ground saturation rates, and changing lake levels in shore areas (NPS 1995, as cited by KellerLynn 2011). Geological map units (i.e., rock formations) susceptible to mass wasting, as identified by KellerLynn 2011 are shown in Table 49.

Measures

- Sediment deposition
- Soils (type and stability)
- Vegetation
- Climate variability

Table 49. Geological Map Units in BICA for which erosion concerns have been identified (KellerLynn 2011).

Age	Geological Map Unit	Erosion concerns
Quaternary	Landslide Deposits (Qls)	Mass wasting – active landslide potential.
Quaternary	Pediment deposits (Qp)	Mass wasting – rockfall debris.
Quaternary	Undifferentiated pediment and in stream beach deposits (Qu)	Mass wasting – rockfall debris.
Upper Cretaceous	Frontier Formation (Kf)	Mass wasting – shale may cause erosion and mass movement.
Upper Cretaceous	Belle Fourche Formation (Kbf)	Mass wasting – shale may cause erosion and mass movement.
Upper Cretaceous	Mowry Shale (Km)	Mass wasting – shale may cause erosion and mass movement.
Lower Cretaceous	Thermopolis Shale (Kt)	Mass wasting – shale may cause erosion and mass movement.
Lower Cretaceous	Kootenai Formation	Mass wasting – landslides and slumps common.
Lower Cretaceous & Upper Jurassic	Cloverly and Morrison Formations, undivided (KJcm)	Mass wasting – shale may cause erosion and mass movement.
Upper Jurassic	Swift Formation (Jes)	Mass wasting – poorly to moderately resistant to erosion.
Upper Jurassic	Rierdon Formation (Jer)	Mass wasting - shale may cause erosion and mass movement.
Upper & Middle Jurassic	Sundance and Gypsum Spring Formations, undivided (Jsg)	Mass wasting – poorly to moderately resistant to erosion.
Triassic	Chugwater Formation	Mass wasting – poorly to moderately resistant to erosion. Parent material for highly erodible soils.
Lower Triassic & Permian	Goose Egg Formation (TRPg)	Mass wasting - shale may cause erosion and mass movement.
Pennsylvanian	Tensleep Sandstone (PNt)	Mass wasting - shale may cause erosion and mass movement.
Lower Pennsylvanian & Upper Mississippian	Amsden Formation (PNMa)	Mass wasting - shale may cause erosion and mass movement.
Middle Mississippian	Madison Group, undivided (Mm)	Mass wasting - shale may cause erosion and mass movement.
Upper Devonian	Three Forks and Jefferson Formations, undivided (Dtj)	Mass wasting - shale may cause erosion and mass movement.
Middle Ordovician	Bighorn Dolomite (Ob)	Mass wasting – Upper part thin- to thick-bedded; lower part massive and resistant.
Middle & Upper Cambrian	Cambrian sedimentary rocks, undivided (Cs)	Mass wasting – slumping possible, notably in Bull Elk Basin. Erosion potential.

Reference Conditions/Values

Reference conditions do not exist for the measures used in this assessment because of the limited data and information available for this resource component. However, recent and on-going monitoring data should provide reference conditions for future assessments.

Data and Methods

Rickets et al. (2004) conducted an assessment of rangeland health in the PMWHR, which includes a portion of BICA west of the Bighorn River. Their study included "a visual appraisal of soil erosion" along each of their survey transects (Rickets et al. 2004, p. 9).

The BICA Geological Resources Inventory Report (KellerLynn 2011) addressed concerns about erosion (specifically mass wasting) in BICA.

Unpublished data from a pilot study of soil aggregate stability in and outside the PMWHR (Crowe 2007) was provided by the GRYN. Aggregate stability is "a measure of the ability of aggregates in the soil to resist being broken down by destructive forces. The higher the aggregate stability of a soil, the less prone it will be to wind and water erosion" (Crowe 2007, citing Hillel 1982). This stability is tested by measuring how much a soil aggregate slakes in water. Soil samples from inside the BICA unit of the PMWHR were compared to samples in BICA but outside the PMWHR.

Current Condition and Trend

Sediment Deposition

Sediment deposition is a major concern for BICA's waterways (KellerLynn 2011), but deposition is also occurring on the terrestrial landscape. NPS staff have observed as much as 1.2 m (4 ft) of sediment piled up against historic structures at Lockhart Ranch (Bromley, pers. comm., 2012). Preliminary research suggests this accumulation occurred during a series of larger events rather than as a gradual process (Bromley, pers. comm., 2012). However, this terrestrial deposition has not been studied in depth and no information or data related to this measure is available.

Soils (type and stability)

Soils in much of BICA are highly susceptible to both wind and water erosion (Ricketts et al. 2004). In 2008, GRYN sampled surface soils in BICA to determine the stability of soils within and outside the PMWHR. Data from that study were made available for this assessment, in order to provide a preliminary analysis as part of the NRCA. The study examined 60 plots, which consisted of three transects each with six samples performed at each transect. Plot locations were selected according to location (half within PMWHR and half outside) and ecotype (i.e., sandy shallow, silty limy, and silty surface). Stability measurements ranged from 1 to 6, with 1 indicating low stability and 6 indicating high stability. GRYN indicated that providing a preliminary examination of the similarity between plots within and outside PMWHR would be beneficial for this NRCA.

Table 50 provides the mean plot stability for all samples, protected samples, and unprotected samples from 2008 GRYN surface soil sampling. The designation of protected versus unprotected depends on the presence of vegetation over the sampling location; vegetation was present in protected samples and absent in unprotected samples. The mean plot stability for all samples and both designations was lower within PMWHR, but not by much. However, unprotected plot means (4.46 within PMWHR, 4.98 outside PMWHR) appear to have the greatest effect on the difference between the all sample means within and outside PMWHR.

Table 50. Mean plot stability (1-6 scale) for surface soil monitoring plots within and outside PMWHR according to protectiveness, 2008. Data provided by GRYN.

	Mean Plot Stability (All Samples)	Mean Plot Stability (Protected Samples)	Mean Plot Stability (Unprotected Samples)
In PMWHR	4.49	4.82	4.46
Outside PMWHR	4.94	4.85	4.98

Individual protected and unprotected sample means were calculated for each monitoring plot. Figure 25 provides the distribution of the sample means by location (within or outside PMWHR) and by protected versus unprotected state. Individual sample means appear to vary according to location within or outside PMWHR (Figure 25). Very few sample plots outside PMWHR yielded a mean stability of less than 4 (all samples = 1/30, protected samples = 3/30, unprotected samples = 1/30), whereas plots within PMWHR exhibited a higher prevalence of mean stability scores less than 4 (all samples = 8/30, protected samples = 8/30, unprotected samples = 9/30). There is no apparent difference between unprotected and protected sites within either location group.

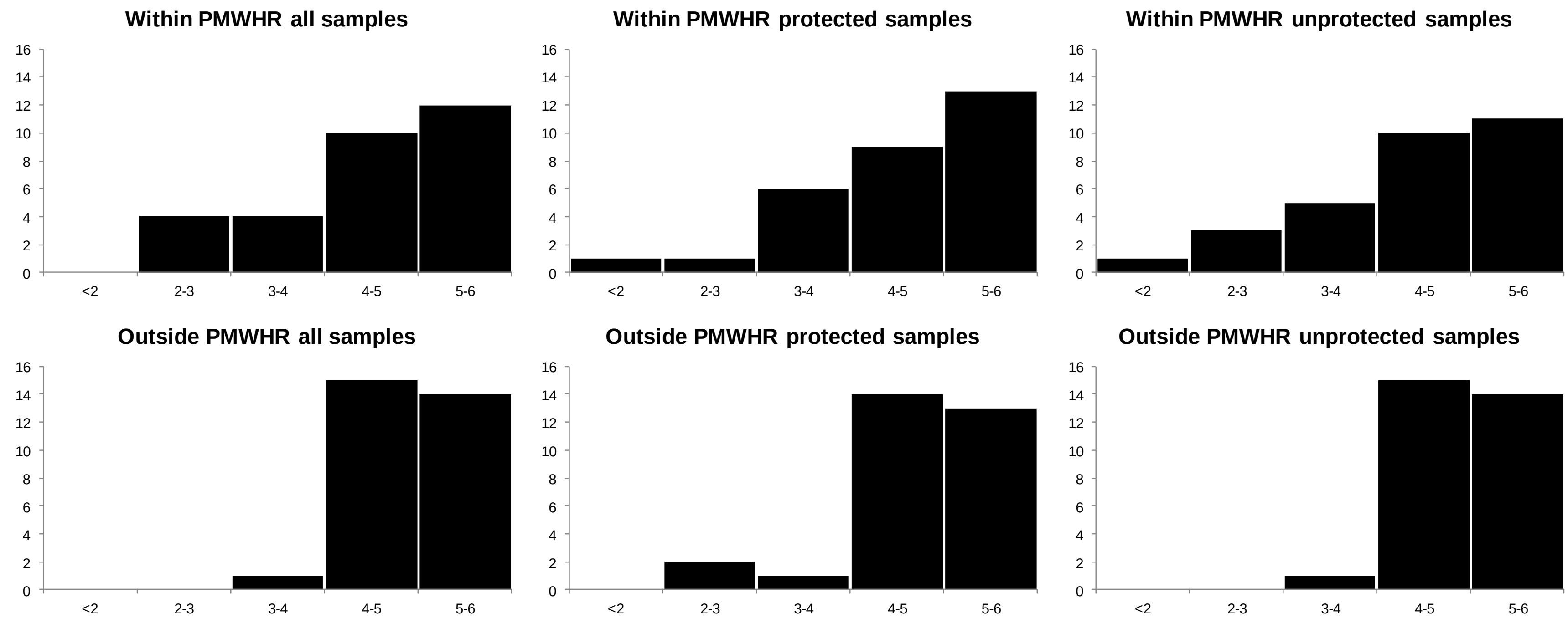


Figure 25. Distribution of mean soil stabilities for 2008 GRYN monitoring sites, within and outside PMWHR: all samples mean stability, protected samples mean stability, and unprotected samples mean stability. To clarify, each histogram displays the distribution of each mean stability type for 30 sites, within or outside of PMWHR. Data provided by GRYN.

The 2008 GRYN surface soil inventory also aimed to understand the differences in stability by ecotype between soils within and outside PMWHR. Mean plot stability calculations, segmented by ecotype and location, indicate the greatest differences in soil stability occur in the Sandy Shallow ecotype. Mean plot stability for all samples and unprotected samples in the Sandy Shallow ecotype exhibited the highest differences in stability (0.964 and 0.921, respectively). In the Silty Limy ecotype, the greatest observed difference in mean plot stability was observed for protected samples (0.663). The differences in the Silty Surface ecotype were most pronounced for calculations of the all samples and unprotected samples mean plot stability (Table 51).

Table 51. Mean plot stability (1-6 scale) for surface soil monitoring plots within and outside PMWHR by ecotype and protectiveness, 2008. Data provided by GRYN.

Ecotype & location (In/Out PMWHR)	Mean plot stability (all samples)	Difference	Mean plot stability (protected samples)	Difference	Mean plot stability (unprotected samples)	Difference
In-SASH[1]	4.087	0.964	4.772	0.414	4.031	0.921
Out-SASH	5.051		5.186		4.952	
In-SILI[2]	5.107	0.184	5.16	0.663	5.118	0.07
Out-SILI	4.923		4.497		5.048	
In-SISU[3]	4.281	0.581	4.555	0.322	4.257	0.579
Out-SISU	4.862		4.877		4.836	

[1]Sandy Shallow ecological type

[2]Silty Limy ecological type

[3]Silty Surface ecological type

Vegetation

Vegetative cover prevents and slows erosion. Removal of vegetation through overgrazing, trampling, fire, or human disturbance, often accelerates erosion rates (Zelt et al. 1999, NPS 2009). As a result, analysis of vegetative cover changes may be useful in assessing erosion susceptibility. However, no data regarding vegetation change in BICA are available at this time.

Climate Variability

Climate (e.g., wind, precipitation) is an important factor in erosional processes, especially in semiarid regions (Kuehn 2003, Graham 2008). According to Wei et al. (2009, p. 308), “rainfall is the initial and essential driving force for natural runoff generation and erosion variation”. Climate variables also impact vegetation patterns, which in turn influence erosion across the landscape. An increase in precipitation in any given environment is generally thought to increase erosion rates in that environment (as reviewed by O’Neal et al. 2005). Therefore, decreased precipitation may reduce erosion rates. However, reduced precipitation could cause a decrease in vegetative cover, increasing the surface area exposed to rainfall and runoff (Clarke and Rendell 2010). In addition, reduced vegetative cover could increase the soil’s exposure to wind erosion (Munson et al. 2011). The frequency of precipitation can also impact erosional processes. Wei et al. (2007) found that rainfall regimes with strong intensities and low frequencies induced more severe runoff and soil erosion than regimes with weak intensities and high frequencies.

Annual precipitation in the BICA area varies from around 17 cm in the south to 45 cm in the north, mostly falling between April and June (Jean et al. 2011). Intense rain storms often occur during these months, producing 2 inches of rain or more per hour (Montana Climate Information 2002, as cited by Ricketts et al. 2004). These intense storms can cause severe erosion of soils with little vegetation (WY DEQ 2010).

<u>Threats and Stressor Factors</u>

Any activity or process that removes the soil's protective layer (vegetation or biological crust) can increase erosion rates in BICA. One of the greatest threats is grazing. Overgrazing, even by native ungulate populations in natural rangelands, decreases vegetative cover, leading to an increase in runoff and soil erosion (Coughenour and Singer 1991, Owens et al. 1996; as cited by Zelt et al. 1999). In addition to native ungulates, horses still graze in the portion of BICA within the PMWHR and there has been public pressure to expand the PMWHR into the Sorenson Extension of BICA to the north of the current PMWHR boundary (Crowe 2007). Cattle trailing takes place in the recreational area by permit (NPS 2004, KellerLynn 2011). Limited cattle grazing occurs along the main road through BICA's south district during permitted cattle drives, and in two small pastures on the northern end of this district (Crowe 2007). Ricketts et al. (2004, p. 33) found that protective biological crusts (primarily mosses and lichens) "tended to be non-existent in areas that had heavier grazing". Fires also remove protective vegetation, allowing increased runoff and extensive erosion (NPS 2009). Erosion control measures may be necessary in burned areas to minimize runoff.

Climate change has the potential to exacerbate BICA's already variable precipitation patterns. Heavy downpours have increased in frequency and intensity across the U.S. over the past several decades, a trend that is expected to continue throughout this century (Karl et al. 2009). Warmer temperatures could decrease snow cover and cause more winter precipitation to fall as rain, lengthening the erosion season (Walker 2001, as cited by Ashton 2010).

<u>Data Needs/Gaps</u>

Little scientific information is available regarding erosion in BICA. NPS staff have observed sediment deposition around historic structures in the area, but a scientific study is needed to determine the extent, timing, and cause(s) of this deposition. Research into the relationship between climate (especially precipitation) and erosion would also be useful to BICA managers.

Currently, GRYN is in the final stages of publishing a vegetation monitoring report that analyzes pilot data collected in BICA in 2011. The report is part of a long-term protocol that will assist GRYN and BICA efforts for determining condition and trend of vegetation and soil cover in the future. This protocol will also assist erosion monitoring through a more in-depth understanding of the vegetative cover measure which is currently not quantifiable.

<u>Overall Condition</u>

Sediment Deposition

BICA staff assigned this measure a *Significance Level* of 3. Deposition of sediment has been observed around several historical structures in the recreational area. However, no data or information has been collected for this measure and a *Condition Level* cannot be assigned at this time

Soils (type and stability)
At this time, the *Condition Level* of the soil type and stability measure (*Significance Level* = 3) is unknown. Recent data collected by GRYN provide some insight into soil stability within the park; the data appear to indicate that surface soils in PMWHR are more prone to erosion when compared to those outside PMWHR. However, these results are preliminary and statistical methods should be employed to determine validity.

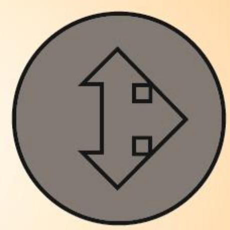
Vegetation
BICA staff also assigned this measure a *Significance Level* of 3. However, vegetation data is not currently available for analysis of change and therefore a *Condition Level* cannot be assigned.

Climate Variability
This measure was given a *Significance Level* of 3. The climate in BICA is highly variable and has a strong influence on erosion. Intense rainstorms, which cause increased runoff and erosion, have increased in the U.S. and are expected to become more frequent in the future. As a result this measure is of moderate concern with a *Condition Level* of 2.

Weighted Condition Score
Since *Condition Levels* could not be determined for several measures, a *Weighted Condition Score* could not be assigned for this component. The condition and trend for erosion in BICA are unknown.

Seeps and Springs

Measures	SL	CL
• Discharge	3	n/a
• Extent of area influenced by springs	3	n/a
• Change in pH, DO, water temperature	2	0
• Macroinvertebrates	2	n/a



WCS = N/A

Sources of Expertise
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4.17 Visitor Experience as Affected by Surface Water Hydrology

Description

Bighorn Lake was formed after closure of the Yellowtail Dam on the Bighorn River in 1965 by the Bureau of Reclamation. The Yellowtail Dam is a multi-purpose dam that provides irrigation, recreation, hydroelectric power, and flood control (BOR 2012). Bighorn Canyon National Recreation Area has over 200,000 visitors a year, many of which participate in fishing and boating on Bighorn Lake, primarily in the southern section of the reservoir (BOR 2010, NPS 2010). Two marinas, Horseshoe Bend and Ok-A-Beh, are particularly important areas of BICA, because they provide recreational access to Bighorn Lake. However, heavy levels of sedimentation exist in Bighorn Lake (BOR and USACE 2010, Plate 25). The deposited sediment is deeper than 15 m (50 ft) in some areas, thereby preventing visitors from safely launching boats (BOR 2010), especially at Horseshoe Bend when water levels are low (Bromley, pers. comm., 2012). Barry's Landing and Ok-A-Beh marina are usually accessible though. Because Bighorn Canyon is a recreation area, it is important to monitor the sediment and lake levels of Bighorn Lake to ensure recreational opportunities are available for the visitors of BICA. Currently, lake level fluctuation from flood to drought is the primary driver of recreational accessibility to the reservoir (Bromley, pers. comm., 2012).

Measures

- Lake levels
- Sedimentation

Reference Conditions/Values

NPS determined a minimum lake level for recreation in summer (Memorial Day to Labor Day) and non-summer seasons as 3,630 and 3,620 feet (reservoir elevations presented in feet for ease of reader), respectively, with a preferred summer level of 3,640 feet (BOR 2009). Other entities, such as the Wyoming Game and Fish (WG&F), have set target minimum lake levels to support waterfowl and the reservoir fishery, and the BOR (2009) determined the following target elevations in an attempt to accommodate everyone's needs:

- October: "An end of October reservoir elevation of at least 3,638 [feet] is necessary to meet most fall and winter operational objectives."
- March: "An end of March reservoir elevation between 3,616.7 and 3,620.6 [feet] to meet most spring and summer operational objectives."
- Lake levels between the end of March and the end of July are guided by a lake level rule curve. During years with high amounts of mountain snowpack this rule cuve can result in the Lake being drafted to as low as 3,603 during the later part of May.
- July: "An end of July reservoir elevation of 3,640 (top of conservation pool) is necessary to meet most summer and fall operational objectives."

BOR (2009) noted that while these levels are target goals, drought conditions or high flood runoff may force some adjustments to the reservoir levels.

The reference condition for other BICA locations (Ok-A-Beh and Barry's Landing) was set at the recommended elevation denoted by the NPS: 3,580 ft.

The reference condition for sedimentation in Bighorn Lake is the projected sediment levels of the reservoir: average annual deposition rate of 3,150 acre-feet (BOR's June 1962 Definite Planning Report).

Data and Methods

The information for this assessment was primarily from Bureau of Reclamation documents and stream gages.

Current Condition and Trend

Lake Levels

NPS has set minimum operating levels for several recreational features in BICA (boat launch ramps, courtesy docks, marina and gas docks, and swim beaches) to ensure accessibility and usability of the recreation area (Table 52). Many of these features were originally usable at lower elevations, but with accumulation of sediment in the reservoir, minimum elevations have had to increase to ensure the safety of visitors when using these sites. BOR takes the NPS-desired operating levels into consideration, but also must consider other goals when making management decisions: irrigation, flood control, power generation, sediment retention, fishery and water fowl resource improvement, and recreation enhancement (BOR 2010).

Table 52. Operating lake levels in BICA (NPS 2010).

Location	Type	Minimum Operating Level (ft)	Top of Ramp Elevation (ft)	Bottom of Ramp Elevation (ft)
Ok-A-Beh	Launch Ramp	3,580	3,648	3,577
	Courtesy Docks	3,590	n/a	n/a
	Marina and Gas Docks	3,600	n/a	n/a
	Swim Beach	3,610	n/a	n/a
Barry's Landing	Launch Ramp	3,580	3,648	3,577
	Courtesy Docks	3,590	n/a	n/a
Horshoe Bend	Launch Ramp	3,617	3,648	3,590
	Courtesy Docks	3,620	n/a	n/a
	Swim Beach	3,625	n/a	n/a
Black Canyon	Courtesy Docks	3,620	n/a	n/a
Medicine Creek	Courtesy Docks	3,620	n/a	n/a

"Severe drought conditions and record-low water supply during 2000-2007 significantly impacted the operation of Yellowtail Dam, resulting in abnormally low levels in Bighorn Lake" (BOR 2010, p. 2). Because of this, the BOR modified the Bighorn Lake operating criteria to better accommodate lake level and river release interests (**Figure 26**) (BOR 2010). These modifications should be beneficial for recreation and the reservoir fishery (BOR 2010). The modifications will, on the average, raise lake levels seven to eight feet between January and

April, three feet between May and June, and four to five feet between July and December (BOR 2010). The increases in reservoir height should provide better boat launching and other recreational opportunities for BICA visitors.

After comparing the proposed lake levels with the 1988-2008 averages (Figure 27), BOR (2010)

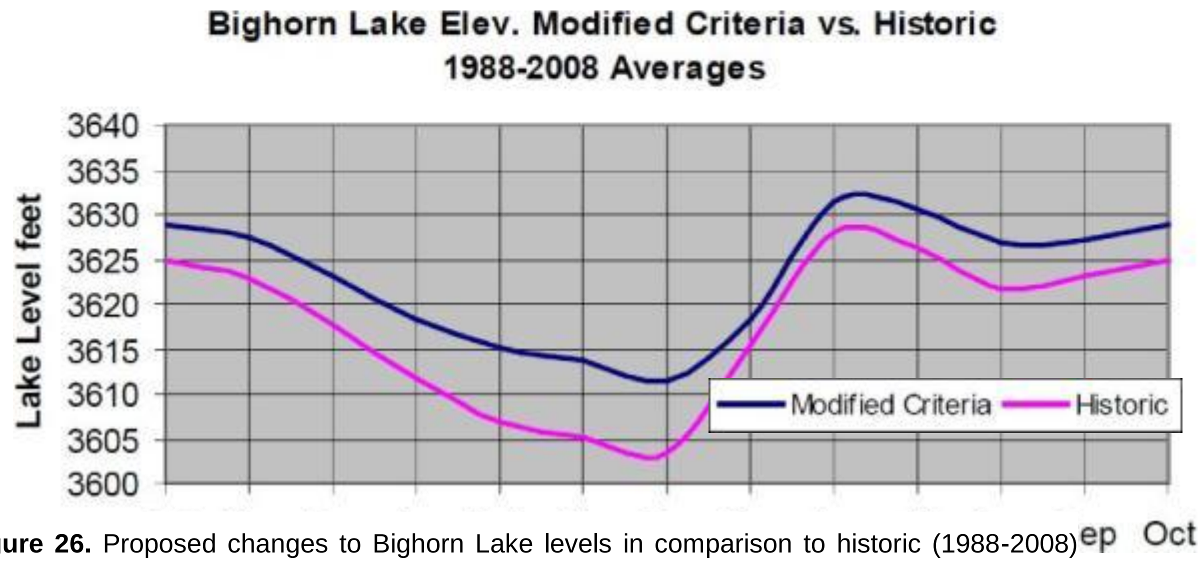

Figure 26. Proposed changes to Bighorn Lake levels in comparison to historic (1988-2008) averages (Taken from BOR 2010).

carefully managed and tracked the 2010 water year to "test [the new criteria's] validity and effectiveness" (p. 29). The reservoir level on 31 October was 3,639.5 feet, falling within the 3,638-3,640 target. Then, by using the current reservoir levels and by using the April-October gains from the previous year, the BOR (2010) created the release rate for November-March: 2,750 cfs to reach the target level of 3,620.6 feet on 31 March. The winter of the 2010 water year had low snowpack and soil moisture levels, forcing the BOR to lower the release rate to 2,000 cfs. Because of this, the 31 March lake level was 3,630 feet, approximately ten feet above the target (BOR 2010). The BOR increased release rates between April and May, and despite the increase, lake levels remained near 3,630 feet. Due to significantly higher than average precipitation and well above average inflow in May and June, the end of July elevation was approximately 3,642 feet, two feet above the target goal (BOR 2010). This level provided better opportunities to maintain recreational opportunities on Bighorn Lake for the rest of summer and into the fall; the amount of inflow in the late summer and early fall months is generally low, so more stored water is needed to maintain desired operational levels. Figure 3 represents the changes in elevation, inflow, and release from April-July in the 2010 water year. While this is only one year of testing, it appears the BOR will be able to meet the target operating levels, unless there are flood or drought conditions. This will be vital in ensuring the access to and usability of BICA for boating and other recreational visitors. There must be continued monitoring of the inflows, elevation, and releases in the coming years to ensure the new BOR targets are effectively being met so that visitors are able to use the recreation area to its full potential.

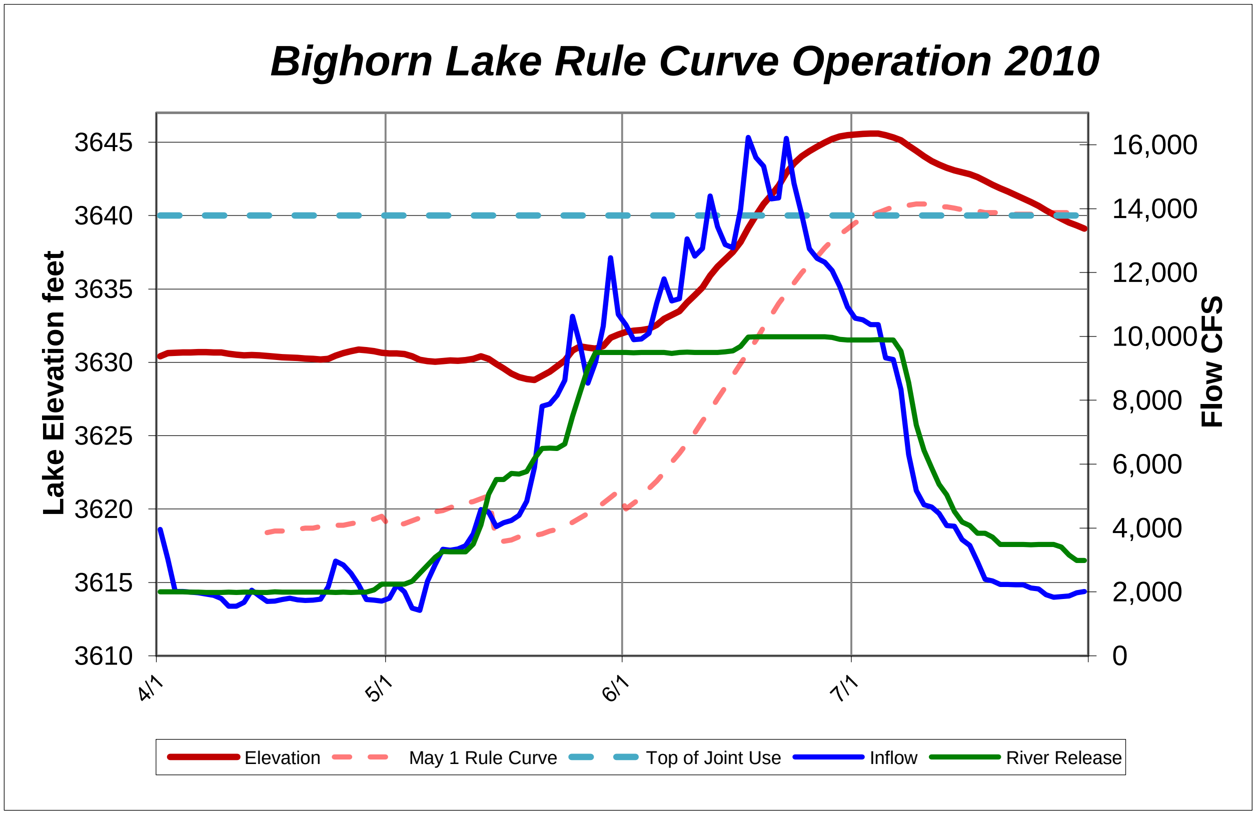

Figure 27. Reservoir operations from April-July in the 2010 water year (Taken from BOR 2010).

<u>Sedimentation</u>

Lake levels are being managed so visitors can access the recreation area, but it is sediment accumulation that is the main factor limiting boat launching opportunities at the Horseshoe Bend boat ramp (BOR 2010). Because there is so much sediment in this area, the safe elevation to launch a boat keeps increasing; the Horseshoe Bend boat ramp was originally useable at elevations as low as 3,590 feet but now cannot be accessed below 3,617 feet (BOR 2010). Now, sediment deposition in the Bighorn River is estimated to equal 4,000 tons per day and in some areas of Horseshoe Bend there is greater than 50 feet of sediment (BOR and USACE 2010). This increase in sediment can especially inhibit access to the boat launch ramp when the water levels are low, forcing Yellowtail Dam managers to increase reservoir elevations during the spring runoff season so that operating lake levels can be maintained throughout the summer (BOR and USACE 2010). However, while the spring runoff season provides the most water input, it also provides the highest sediment loads, resulting in an increase in sediment in the reservoir (BOR and USACE 2010). This results in a cyclic process, in which an increase in water is needed to counteract the high sediment levels, but the increase in water results in more sediment deposition.

Sediment accumulation is an expected process that results from building and maintaining a reservoir. When the Yellowtail Dam was completed in 1967, the BOR mapped the bathymetry of Bighorn Lake to calculate the sediment capacity, along with the projected fill rate. The area was resurveyed in 1982 and again in 2007 to analyze the amount of sediment in Bighorn Lake.

Originally, the BOR estimated total 100-year sediment accumulation to be 315,000 acre-feet at elevation 3,660 and below (Ferrari 2010). BOR estimated 75,000 acre-feet of the 315,000 acre-feet would accumulate above elevation 3,547 (top of Bighorn Lake's inactive pool), leaving the remaining 240,000 acre feet below 3,547 feet (inactive pool elevation) (Ferrari 2010). From 1965-2007, a total of 103,415 acre-feet of sediment accumulated in Bighorn Lake, with 39,776 acre-feet below 3,547 feet and 63,685 acre-feet above 3,547 feet (Ferrari 2010). This represents a rate of 2,480 acre-feet per year, 670 acre-feet below the projected average annual rate of 3,150 acre-feet (Ferrari 2010). Bighorn Lake's total capacity at elevation 3,657 (top of exclusive flood pool) as of July 2007 was 1,311,725 acre-feet (Ferrari 2010), leaving the storage space lost to sediment of 103,415 well below that mark. It should be noted that the average annual sediment deposit rate from 1982-2007 was only 1,986 acre-feet, compared to the 1965-1982 rate of 3,221 acre-feet (Ferrari 2010). This is a 38% reduction in sediment inflow, and is largely a result of a 22% decrease in average water inflow from 1982-2007 (Ferrari 2010). The projected and actual sedimentation levels are summarized in Table 53.

Table 53. Projected and actual sediment deposition in Bighorn Lake (Blanton 1986, Ferrari 2010).

	Projected total sediment volume (acre-feet)	Actual total sediment volume (acre-feet)	Projected average annual deposition rate (acre-feet)	Actual average annual deposition rate (acre-feet)
1966-1982	47,250	53,950	3,150	3,221
1982-2007	126,000	103,415	3,150	1,986

Threats and Stressor Factors

Sediment accumulation at the Horseshoe Bend Marina is an ongoing threat to recreation in BICA. While water elevation is the limiting factor for boat launching ramp accessibility, it is sediment accumulation that is forcing the necessary elevations to increase. The new BOR reservoir elevation criteria should accommodate for necessary elevations for boat launching at Horseshoe Bend, but sediment deposition will continue; sediment deposition is a part of creating and maintaining a reservoir and a remnant oxbow (such as Horseshoe Bend) will accumulate high levels of sediment. However, Horseshoe Bend will eventually accumulate sediment loads too high to allow for boat launching, regardless of reservoir elevation.

Low reservoir levels are a continuing threat to recreational use on Bighorn Lake. From 2000-2007, BICA experienced drought conditions that extensively reduced inflow and reservoir levels (BOR 2010). These lower lake levels inhibit visitors from being able to access the boat ramps above the Yellowtail Dam, and as sediment levels increase in certain areas this problem will become more apparent; this is a major concern to the local economy (Jean, pers. comm., 2012). The BOR has since developed ways to more effectively manage the Bighorn Lake elevation levels, but years of low precipitation still pose a threat to reservoir levels. Conversely, high-precipitation years can also limit access. In 2011, many of the lake campgrounds and swimming beaches were inundated for most of the summer (Bromley, pers. comm., 2012).

There is a threat of invasive species colonizing the floodplain when reservoir elevation is low. Leafy spurge (*Euphorbia esula*) and Russian knapweed (*Centaurea repens*) are both listed as weedy invasive species in Wyoming, and have the potential to take over riparian areas (Jacobs et al. 1996). Leafy spurge has not been found in BICA, but Russian knapweed is present in the park (Jacobs et al. 1996). In addition, whitetop thistle (*Lepidium draba*) and saltcedar (*Tamarix ramosissima*) are two additional species of concern regarding expansion within riparian areas in the park; Wood and Rew (2005) note that extensive infestations of invasive species existed within the southern portion of YHWMA.

Data Needs/Gaps

Data needs for this component include continued monitoring of elevation levels in comparison to new BOR targets, along with continued monitoring of sediment levels in comparison to projected accumulation levels.

Overall Condition

Lake Levels

While reservoir elevations have had to slowly increase to counteract sedimentation, BOR has largely been able to maintain reservoir elevations specified by NPS for recreational use. The lake level measure (*Significance Level* of 3) *Condition Level* was rated 0, meaning it is of no concern.

Sedimentation

Sedimentation (*Significance Level* of 2) is occurring throughout the reservoir, especially near Horseshoe Bend, and minimum water elevations must continually increase to counteract the higher levels of sediment. However, sedimentation is an intrinsic part of reservoirs, and although sediment levels exceed 50 feet near Horseshoe Bend, the overall accumulation of sediment, along with the average annual sediment rates are lower than the projected levels calculated during construction (103,415 acre-feet of storage displaced by sediment compared to 315,000 acre-feet) (Table 2). Even though the sediment levels were far below the expected levels, the *Condition Level* for this measure is 1, indicating low concern. The reason for elevating the *Condition Level* is that continued sediment deposition will limit access to the reservoir in the future, especially during low-water years (Bromley, pers. comm., 2012; Jean, pers. comm., 2012).

Weighted Condition Score

The *Weighted Condition Score* for this component is 0.133. Because the lake and sediment levels meet the original expectations for the reservoir (though these levels may not necessarily be desirable for recreational purposes), visitor experience as affected by surface water hydrology is of low concern.

Visitor Experience as Affected by Surface Water Hydrology

Measures	SL	CL
• Lake Levels	3	0
• Sedimentation	2	1

WCS = 0.133

Sources of Expertise

Stephanie Micek, Bureau of Reclamation
Lenny Duberstein, Bureau of Reclamation
Dan Jewell, Bureau of Reclamation
Tom Sawatzke, Bureau of Reclamation

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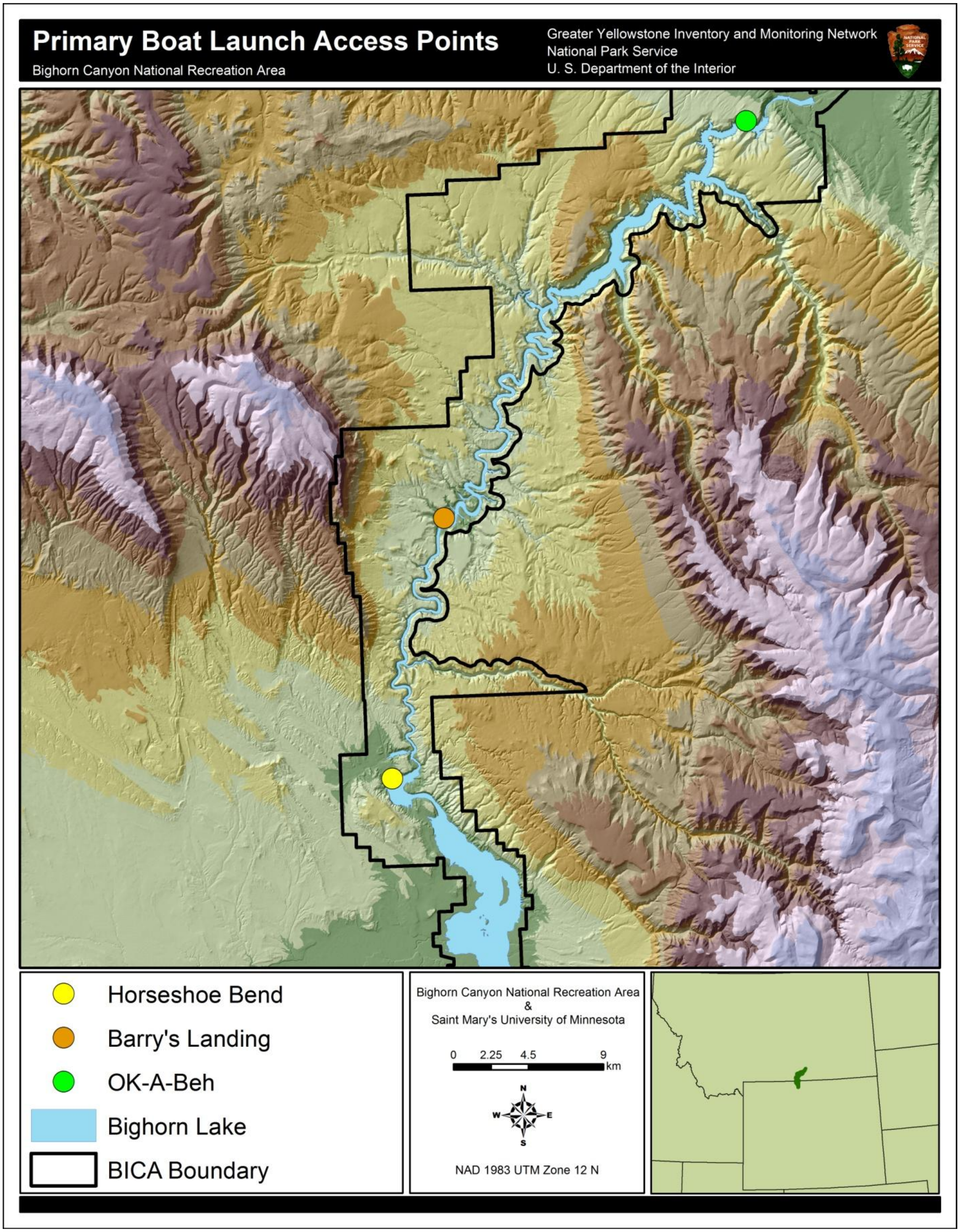


Plate 25. Boat launch access points.

Chapter 5 Discussion

5.1 Component Data Gaps

The identification of key data and information gaps is an important objective of the NRCA process. Data gaps or needs are those pieces of information that are currently unavailable, but would help to inform the status of the overall condition of a key resource component. Data gaps/needs exist for all key resource components assessed in this NRCA, and are summarized in Table 54.

Table 54. Data gaps/needs for components analyzed for the BICA NRCA.

Component	Data Gaps/Needs
Cottonwood-dominated Woodlands	-Updated vegetation inventory in the riparian area.
Cushion Plant Community	-Total area of cushion plant communities in BICA. -Data and literature regarding the cryptogamic soils in the park; local, expert knowledge is the primary source of information for these soils. -Research regarding the reason for different assemblages of cushion plant communities.
Sagebrush Steppe Community	-Protocol for continued monitoring to develop reference condition and provide comparable data in the future (in progress).
Juniper/Pine/Mountain Mahogany Community	-Updated land cover and vegetation mapping (in progress). -Quantitative data regarding juniper expansion via on-the-ground surveys, remote sensing, or aerial photo-interpretation.
Bighorn Sheep	-Updated population estimates. -An advanced analysis of correlations between precipitation and population trends. -An updated analysis of food availability and forage usage given changing vegetation composition in the park.
Wild Horses	-A re-evaluation of plots sampled by Rickets et al. (2004).
Bats	-Surveys expanding on and comparable to data developed by Keinath during the early 2000s. -Identification and synthesis of data sources unavailable during this assessment.
Game Birds	-Monitoring of BBS route 92037. -Species-specific surveys, especially for wild turkey and ring-necked pheasant.
Land Birds	-Monitoring of bird populations in the northern portion of the park. -Increased sampling using the IMBCR protocol.
Peregrine Falcon	-Establishment of an annual intensive survey, including nearby drainages and large cliffs. -Observations during the early portion of nesting season to expand knowledge of nesting success.
Bighorn Lake Species	-A creel survey. -Data on the use and importance of habitats influenced by reservoir operation.
Tailwater Trout Fishery	-Continued monitoring of fish populations and aquatic invasive species. -Research examining the relationship between flushing flows, channel re-establishment efforts, and fish abundance.

Table 54. Data gaps/needs for components analyzed for the BICA NRCA. (continued)

Component	Data Gaps/Needs
Water Quality	-Data regarding inputs of pesticides and other contaminants.
Viewscape	-Incorporation of new GIS data sets into future analyses. -Continued monitoring of observation points utilized in this assessment.
Seeps and Springs	-Data explaining depth to groundwater table. -Continued water quality monitoring at seeps and springs. -Continued surveys of macroinvertebrate communities. -Full vegetation survey of BICA to better understand vegetation communities near springs.
Erosion	-Research regarding the relationship between climate and erosion in the park.
Visitor Experience as Affected by Surface Water Hydrology	-Continued monitoring of lake elevation levels and sedimentation.

5.2 Component Condition Designations

Of the 17 components analyzed for this assessment, condition is unknown for nine (Table 55). The three plant community components with unknown condition based on this assessment's methods (cushion plant community, sagebrush steppe community, and juniper/pine/mountain mahogany community) have data and literature available for them, and protocols in development for future monitoring, but the lack of long-term data and reference condition makes defining condition impractical. In the case of the bats, land birds, and game birds components, data are available for these important resources, but goals for management that help inform reference condition do not exist, making condition not possible to designate for most measures. For the bighorn lake species and seeps and springs components, condition is difficult to determine due to the lack of recent quantitative data. Plenty of data exist for the erosion component, and continued monitoring should allow for a clearer picture of condition in the future.

For components with enough data and information available for complete assessment, condition was of low concern for all except two components (cottonwood-dominated woodlands and wild horses). In the case of both components with higher concern levels, the condition of those resources is largely beyond the control of park management. The reason for the deterioration of the cottonwood-dominated woodlands is flood regulation by dams, which are administered by other agencies with different goals. The wild horse population spans an area that includes land owned by different agencies and is managed by BLM. Bighorn sheep, peregrine falcons, and the tailwater trout fishery are three biological components with condition defined as of low concern, but are still sensitive to changes as past evidence indicates. The conditions of the water quality and viewscape components are both of low concern and should be stable in the near future. The visitor experience as affected by surface water hydrology component is complex in that even though the reservoir is filling and recreation opportunities will continue to decline into the future, the reservoir is operating within the original expectations and, therefore, condition is of low concern.

Table 55. Summary of component-level condition and trend.

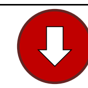
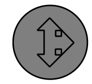
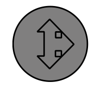
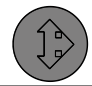
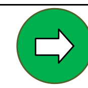
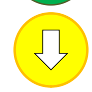
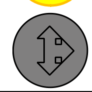
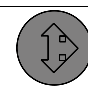
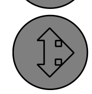
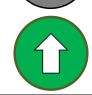
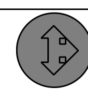
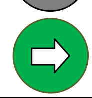
Component	WCS	Condition
Biological Composition		
Ecological Communities		
Cottonwood-dominated Woodlands	1.000	
Cushion Plant Community	N/A	
Sagebrush Steppe Community	N/A	
Juniper/Pine/Mountain Mahogany Community	N/A	
Mammals		
Bighorn Sheep	0.296	
Wild Horses	0.564	
Bats	N/A	
Birds		
Game Birds Species	N/A	
Land Birds	N/A	
Peregrine Falcons	0.167	
Fish		
Bighorn Lake Species	N/A	
Tailwater Trout Fishery	0.166	

Table 55. Summary of component-level condition and trend. (continued)

Environmental Quality			
	Water Quality	0.333	
	Viewscape	0.333	
Physical Characteristics			
	Seeps and Springs	N/A	
	Erosion	N/A	
	Visitor Experience as Affected by Surface Water Hydrology	0.133	

5.3 Park-wide Condition Observations

As a National Recreation Area, the context for the assessment of the resources within BICA is different from a traditional National Park. BICA's enabling legislation identifies the park's purpose as to "provide for public outdoor recreation use and enjoyment of Yellowtail Reservoir and lands adjacent thereto and for the preservation of the scenic, scientific and historic features contributing to public enjoyment of such lands and waters" (15 U.S.C. § 460t [a]). The conditions of three of the four components assessed in this report that relate directly to the opportunity for recreation (i.e., tailwater trout fishery, viewscape, and visitor experience as affected by surface water hydrology) are currently of low concern and the other is unknown. No single administrative agency or landowner completely controls these resources and therefore, the status of these resources is a testament to the ability of stakeholders to work together for the benefit of resource users. Conversations with topical experts during this assessment indicate that management of resources, especially related to the reservoir, relies on collaboration and input from the public. The affiliations of individuals identified in the sources of expertise sections within Chapter 4 provide an account of some of the administrative agencies and stakeholders that collaborate with and assist BICA management (Table 56).

Table 56. Individuals identified as sources of expertise for NRCA components.

Name	Agency	Title
Suzanne Morstad		Local Naturalist
Jared Bybee	BLM	Rangeland Management Specialist
Stephanie Micek	BOR	
Lenny Duberstein	BOR	
Dan Jewell	BOR	
Tom Sawatzke	BOR	
Judson Finley	Memphis University	Assistant Professor
Dave Stagliano	Montana Natural Heritage Program	Aquatic Ecologist
Jay Sumner	Montana Peregrine Institute	Director
Denine Schmitz	Montana State University	Riparian Ecologist
Shawn Stewart	MTFWP	Wildlife Biologist
Mike Ruggles	MTFWP	Fisheries Biologist
Ken Frazer	MTFWP	Fisheries Manager
Jeff Arnold	NPS	Aquatic Ecologist
Cassity Bromley	NPS BICA	Natural Resource Program Manager
Bill Pickett	NPS BICA	Natural Resource Specialist
Cathie Jean	NPS GRYN	I&M Management Assistant
Melanie Myers	NPS Intermountain Region	GIS Analyst
Matt Rickets	NRCS	Rangeland Management Specialist
Chris White	Rocky Mountain Bird Observatory	Biologist
Nick Van Lanen	Rocky Mountain Bird Observatory	Biologist
Robert Kissell	Univ. of Arkansas - Monticello	Associate Professor
Tom Easterly	WG&F	Wildlife Biologist
Mark Smith	WG&F	Wildlife Biologist
Doug Keinath	WYNDD	Biologist

Many of the components with less focus on recreation lack enough data and information to define condition. However, protocols are in development by NPS that, once implemented, will allow for a better understanding of condition. In particular, recent efforts by BICA and GRYN to develop vegetation monitoring protocols should alleviate data gaps relating to all of the vegetation community components. For other components with unknown condition, sufficient data may exist, but reference conditions for measures are not defined at this time.

In conclusion, the nature of BICA's designation as a National Recreation Area differentiates it from more traditional NPS units analyzed according to standard metrics that assess the condition of a given resource only according to the ecological, biological, or physical health, excluding the opportunity for human use. In addition, while all NPS units provide a service to people regardless of the designation, a unit specifically designated as a National Recreation Area entails additional requirements to provide resource use opportunities to the public. When analyzing the condition of BICA's resources based on aforementioned implications, park resources are generally in good condition and this reflects the efforts of NPS and BICA, as well as all the individuals and agencies that cooperate with them.

Appendices

Appendix A. MTFWP survey numbers from the Pryor Mountains, 1997-2011 (data provided by Shawn Stewart).

Year	Yearling Rams	2 yr Rams	3 yr Rams	4+ yr Ram	Ewes	Lambs	Total	Lambs/100 Ewes	Rams/100 Ewes
1997	0	2	6	14	57	6	85	11	39
1998	2	1	2	7	53	13	78	25	23
1999	2	3	0	5	39	15	64	38	26
2000	6	2	2	1	30	1	42	3	36
2001	0	1	5	2	38	6	52	16	21
2002	No Count								
2003	1	2	0	1	22	7	33	32	18
2004	1	3	2	-	21	4	31	19	29
2005	3	6	3	11	35	8	66	23	66
2006	3	4	1	81	40	9	65	22	40
2007	No Count								
2008	4	3	3	10	43	15	78	35	47
2009	2	0	3	9	21	8	43	38	67
2010	1	0	0	5	16	3	25	19	38
2011	0	1	2	4	14	8	31	57	50

Appendix B. Monthly precipitation averages for BICA, 1920-2010 (PRISM 2010b).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1920	0.11	0.1	0.07	0.29	1.05	0.75	0.3	0.3	0.11	0.15	0.09	0.16	3.48
1921	0.16	0.03	0.04	0.07	1.9	0.76	0.11	0.09	0.06	0.03	0.51	0.24	4
1922	0.48	0.25	0.06	1.34	0.85	0.88	0.79	1.06	0.09	0.61	0.59	0.36	7.36
1923	0.08	0.32	0.29	0.63	0.5	0.93	0.83	0.73	2.61	0.5	0.24	0.35	8.01
1924	0.47	0.54	0.94	0.13	0.29	0.49	0.84	0.04	0.59	0.51	0.14	0.48	5.46
1925	0.19	0.04	0.2	1.18	1.04	0.85	0.56	0.28	0.56	1.28	0.07	0.22	6.47
1926	0.33	0.19	0.08	0.33	1.56	0.79	1.02	0.67	1.54	0.29	0.27	0.09	7.16
1927	0.43	0.29	0.19	1.29	2.05	1	0.37	1.02	0.5	0	0.63	0.33	8.1
1928	0.5	0.55	0.39	0.2	0.51	1.49	2.18	1.04	0.25	0.61	0.52	0.29	8.53
1929	0.49	0.93	0.6	0.9	0.67	0.65	0.58	0.1	0.75	0.58	0.85	0.54	7.64
1930	0.53	0.21	0.23	0.16	0.88	1.21	0.51	1.93	0.37	1.19	0.03	0	7.25
1931	0.01	0.07	0.37	1.04	0.73	0.72	0.19	0.34	1.15	0.87	0.27	0.15	5.91
1932	0.42	0.05	0.76	0.68	1.44	2.65	0.35	0.33	0.83	0.41	0.29	0.51	8.72
1933	0.51	0.23	0.23	0.43	1.09	0.69	0.01	0.79	0.06	0.71	0.04	0.44	5.23
1934	0.04	0.11	0.56	0.32	0.06	1.03	0.55	0.15	0.37	0.98	0.25	0.3	4.72
1935	0.04	0.14	0.59	1.25	1.15	0.66	0.15	0.9	0.18	0.19	0.2	0.04	5.49
1936	0.27	0.56	0.6	0.53	0.42	0.98	0.56	0.33	0.35	0.36	0.18	0.19	5.33
1937	0.32	0.83	0.6	0.25	0.77	1.62	1	0.07	0.45	0.53	0.19	0.51	7.14
1938	0.38	0.22	0.7	0.34	2.99	1.67	1.23	0.46	0.28	0.54	0.24	0.13	9.18
1939	0.23	0.38	0.25	0.42	1.46	2.92	0.42	0.66	0.4	0.08	0	0.26	7.48
1940	0.79	0.47	0.18	1.43	0.33	2.56	1.76	0.01	1.19	1.27	0.1	0.04	10.13
1941	0.04	0.04	0.13	1.46	1.66	1.29	0.71	0.66	2.59	0.62	0.26	0.32	9.78
1942	0.36	0.08	0.22	0.58	2.39	0.4	0.29	0.43	0.92	0.83	0.75	0.32	7.57
1943	0.6	0.5	0.39	0.18	0.89	2.33	0.35	0.67	0.07	0.85	0.27	0.1	7.2
1944	0.39	0.19	0.15	0.81	1.76	3.43	0.36	0.03	1.52	0.17	0.18	0.2	9.19
1945	0.41	0.05	0.66	0.16	0.86	2.09	0.81	1.08	0.9	0.18	0.21	0.65	8.06
1946	0.3	0.3	0.98	0.03	0.78	1.5	1.37	0.67	1.36	0.78	0.39	0.66	9.12
1947	0.13	0.62	0.15	0.48	0.91	1.63	0.31	0.29	0.53	1.04	1.99	0.39	8.47
1948	0.48	0.18	0.1	1.08	1.07	1.74	1.28	0.44	0.42	0.06	0.12	0.12	7.09
1949	0.45	0.12	0.45	0.23	1.71	1.93	0.7	0.01	0.53	0.85	0.12	0.3	7.4
1950	0.36	0.01	0.2	0.21	0.59	1.09	0.57	0.47	1.28	0.06	0.31	0.11	5.26
1951	0.13	0.03	0.13	0.78	0.46	0.96	1.94	0.4	0.33	0.9	0.1	0.3	6.46
1952	0.21	0.13	0.41	0.51	1.23	0.61	0.55	0.44	0.13	0	0.24	0.11	4.57
1953	0.1	0.37	0.27	0.47	1.43	1.1	0.1	0.29	0.52	0.57	0.27	0.14	5.63
1954	0.23	0.06	0.92	0.26	1.22	1.25	0.3	0.28	0.05	0.1	0	0.01	4.68
1955	0.07	0.29	0.35	0.78	1.53	1.41	0.09	0.4	0.57	0.46	0.2	0.31	6.46
1956	0.13	0.05	0.39	0.84	0.7	1.46	0.15	0.76	0.11	0.04	0.16	0.06	4.85
1957	0.07	0.31	0.2	1.6	1.99	1.59	0.06	0.45	0.61	0.65	0.1	0.03	7.66
1958	0.11	0.41	0.11	0.68	0.4	2.23	2.26	0.53	0.12	0.52	0.43	0.22	8.02
1959	0.15	0.41	0.15	1.26	0.72	0.82	0.19	0.12	0.72	0.88	0.55	0.27	6.24

Appendix B. Monthly precipitation normals for BICA, 1920-2010 (PRISM 2010b). (continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1960	0	0.15	0.12	0.2	0.39	0.45	0.08	1.01	0.18	0.38	0.36	0.26	3.58
1961	0	0.08	0.38	0.49	1.8	0.09	1.72	0.15	2.44	0.3	0.03	0	7.48
1962	0.53	0.04	0.1	0.44	2.04	1.74	0.87	1.02	0.66	0.07	0.79	0.1	8.4
1963	0.62	0.17	0	1.79	1.27	0.8	0.81	0.14	1.1	0.04	0.16	0.31	7.21
1964	0.11	0.23	0.16	2.8	2.24	2.91	0.04	2.04	0.03	0.33	0.23	0.43	11.55
1965	0.31	0.11	0.24	0.3	1.8	2.03	0.63	1.32	1.05	0.29	0.02	0.07	8.17
1966	0.04	0	0.04	0.77	0.17	0.95	0.09	0.67	0.7	0.08	0.33	0.13	3.97
1967	0.17	0.31	0.43	0.61	0.79	3.45	0.34	0.58	0.41	0.32	0.15	0.75	8.31
1968	0.15	0.11	0.09	0.03	1.14	2.48	0.75	1.9	0.76	0.12	0.29	0.29	8.11
1969	0.34	0.01	0.04	1.02	0.8	4.12	0.32	0.12	0.45	0.67	0.32	0.03	8.24
1970	0.16	0.08	0.5	1.08	1.46	0.85	0.32	0.03	1.43	0.17	0.29	0.1	6.47
1971	0.42	0.53	0.4	0.76	1.22	0.42	0.22	0.82	0.87	1.86	0.3	0.5	8.32
1972	0.78	0.02	0.23	0.3	0.96	0.97	0.5	1.96	0.23	0.57	0.14	0.18	6.84
1973	0.08	0.04	0.67	1.54	0.06	1.17	1.13	0.23	2.48	0.17	0.38	0.1	8.05
1974	0.09	0	0.09	0.53	1.33	1.5	1.06	0.77	0.28	1.46	0.55	0.01	7.67
1975	0.64	0.11	0.32	1.27	2.02	0.96	1.23	0.06	0.19	1.43	0.38	0.07	8.68
1976	0.12	0.17	0.07	1.41	0.13	1.62	0.16	1.61	1.04	0.34	0.37	0	7.04
1977	0.37	0	0.51	0.43	1.15	0.93	0.63	1.34	0.53	0.39	0.07	0.39	6.74
1978	0.32	0.83	0.03	1.67	3.48	0.18	0.63	0.26	2.6	0.02	0.53	0.34	10.89
1979	0.41	0.03	0	0.31	1.31	0.85	0.34	0.94	0.04	0.51	0.29	0	5.03
1980	0.12	0.04	0.49	0.05	2.52	0.93	0.49	0.95	0.79	0.41	0.26	0.09	7.14
1981	0.09	0.3	0.55	0.47	4.18	0.55	0.53	0.22	0.15	0.92	0.04	0.07	8.07
1982	0.25	0.1	0.37	0.17	0.98	2.76	1.15	0.89	0.82	0.56	0.06	0.36	8.47
1983	0.01	0.01	0.36	0.03	1.36	1.34	0.67	0.38	0.61	0.87	0.16	0.21	6.01
1984	0.25	0.1	0.5	0.93	0.82	0.73	0.73	0.26	0.6	0.12	0.09	0.18	5.31
1985	0.22	0.04	0.32	0.13	0.63	1.11	0.72	0.66	1.27	0.14	0.27	0.31	5.82
1986	0.1	0.5	0.26	0.78	0.7	0.95	0.34	1	1.88	0.3	0.46	0	7.27
1987	0.06	0.3	0.55	0.03	2.87	0.7	2.12	0.58	0.41	0	0.32	0.02	7.96
1988	0.1	0.23	0.09	0.22	2.88	0.28	0.01	0.12	0.62	0.39	0.33	0.37	5.64
1989	0.38	0.2	0.56	0.43	1.78	0.12	0.85	0.82	0.19	0.86	0.13	0.69	7.01
1990	0.12	0.04	0.9	0.65	0.75	0.27	1.17	0.87	0.18	0.41	0.12	0.19	5.67
1991	0.11	0.17	0.43	1.37	1.45	2.38	0.34	0.1	1.67	0.38	0.42	0.21	9.03
1992	0.01	0	0.27	0.59	1.32	3.2	1.03	0.52	0.12	0.36	0.3	0.43	8.15
1993	0.28	0.09	0.06	0.96	1.09	1.01	2.87	0.55	0.04	1.19	0.12	0.05	8.31
1994	0.1	0.19	0.47	0.55	0.55	0.16	0.43	0.11	0.92	1.41	0.14	0.01	5.04
1995	0.07	0.01	1.04	0.93	1.35	0.75	1.43	0.16	1.2	0.25	0.14	0.11	7.44
1996	0.44	0.41	0.6	0.49	1.88	0.52	0.02	0.27	1.09	0.08	0.29	0.42	6.51
1997	0.29	0.19	0.1	0.39	0.77	2.79	2.09	0.62	0.31	1.26	0.09	0.11	9.01
1998	0.68	0.14	0.35	0.29	0.41	1.74	0.92	1.2	0.7	0.99	0.29	0.12	7.83
1999	0.13	0.12	0.05	1.12	1.04	0.65	0.18	0.2	0.46	0.24	0.08	0.42	4.69

Appendix B. Monthly precipitation normals for BICA, 1920-2010 (PRISM 2010b). (continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2000	0.42	0.26	0.24	0.47	1.5	0.57	0.54	0.25	0.37	0.81	0.14	0.24	5.81
2001	0.05	0.31	0.16	0.7	0.27	2.11	0.23	0.13	1.22	0.42	0.2	0.19	5.99
2002	0.2	0.09	0.33	0.53	0.47	0.58	0.34	0.16	0.45	0.33	0.72	0.03	4.23
2003	0.21	0.31	0.56	0.41	0.85	0.75	0.19	0.19	0.24	0.24	0.05	0.32	4.32
2004	0.09	0.29	0.03	0.22	0.23	0.57	1.24	0.29	0.67	0.47	0	0.07	4.17
2005	0.17	0.16	0.31	2.28	2.67	0.99	0.3	0.56	0.68	0.79	0.28	0.09	9.28
2006	0.11	0.09	0.63	0.26	0.98	0.52	0.2	0.15	1.16	1.14	0.17	0.1	5.51
2007	0.16	0.37	0.65	0.91	1.3	0.69	0.48	0.29	0.24	1.78	0.17	0.15	7.19
2008	0.43	0.06	0.21	0.16	2.71	0.38	0.21	0.44	1.21	0.93	0.42	0.39	7.55
2009	0.37	0.1	0.2	0.49	0.39	2.66	0.63	0.24	0.21	0.47	0	0.18	5.94
2010	0.34	0.17	0.12	0.28	1.85	1.19	0.46	1.01	0.2	0.16	0.45	0.18	6.41
Mean	0.26	0.21	0.33	0.67	1.23	1.28	0.68	0.56	0.7	0.54	0.28	0.23	6.967

Appendix C. Reference condition for BICA land birds. Estimated densities per km^2 (D), population sizes (N), percent coefficient of variation of estimates (% CV) and number of independent detections (n) of breeding bird species on BLM lands in Wyoming, 2010. S indicates the number of transects used in analyses. Priority species are bolded (White et al. 2011).

	BLM WY (S = 56)			
Species	**D**	**N**	**% CV**	**n**
American crow	0.45	32,526	70	10
American kestrel	0.27	19,275	82	4
American robin	3.49	250,204	57	14
barn swallow	0.23	16,804	67	6
black-billed magpie	0.34	24,746	45	13
black-capped chickadee	8.22	590,276	86	22
black-throated gray warbler	0.02	1,627	100	1
blue-gray gnatcatcher	0.52	37,290	76	3
Brewer's blackbird	0.97	69,444	54	8
Brewer's sparrow	**38.37**	**2,754,106**	**12**	**483**
brown creeper	**0.14**	**10,025**	**100**	**1**
brown-headed cowbird	1.1	79,022	53	26
Canada goose	0	26	86	1
chestnut-collared longspur	**0.84**	**60,279**	**72**	**5**
chipping sparrow	5.45	391,041	41	26
Clark's nutcracker	**3.14**	**225,171**	**80**	**10**
cliff swallow	2.67	191,498	55	10
common grackle	0.56	40,408	92	5
common nighthawk	0.13	9,268	92	1
common raven	0.96	68,796	48	25
dark-eyed junco	0.07	4,745	90	5
downy woodpecker	0.24	17,110	19	3
dusky flycatcher	**0.6**	**43,111**	**36**	**18**
eastern kingbird	0.07	5,257	95	2
European starling	0.01	883	85	1
grasshopper sparrow	**0.57**	**41,150**	**64**	**31**
gray jay	0.35	25,300	101	4
green-tailed towhee	6.34	454,916	21	33
horned lark	51.88	3,723,758	24	740
house wren	0.18	12,790	101	7
killdeer	0.43	30,952	40	25
lark bunting	**5.73**	**411,132**	**40**	**330**
lark sparrow	3.95	283,325	53	55
lazuli bunting	**0.01**	**373**	**87**	**1**
Lincoln's sparrow	0.68	48,902	98	3
loggerhead shrike	0.18	12,860	70	3
MacGillivray's warbler	0.16	11,538	100	3
McCown's longspur	**2.53**	**181,841**	**83**	**22**
mountain bluebird	4.19	300,446	56	15
mountain chickadee	10.39	745,894	62	10
mourning dove	0.64	46,113	22	33
northern flicker	0.18	12,728	46	7
northern harrier	**0.24**	**17,318**	**54**	**5**
olive-sided flycatcher	**0.02**	**1,205**	**101**	**1**
ovenbird	0.03	1,832	82	5
pine siskin	0.3	21,452	72	2
plumbeous vireo	0.04	3,193	101	3
pygmy nuthatch	0.13	9,396	100	1
red crossbill	**0.09**	**6,280**	**101**	**2**

Appendix C. Reference condition for BICA land birds. Estimated densities per km2 (D), population sizes (N), percent coefficient of variation of estimates (% CV) and number of independent detections (n) of breeding bird species on BLM lands in Wyoming, 2010. S indicates the number of transects used in analyses. Priority species are bolded (White et al. 2011). (continued)

	BLM WY (S = 56)			
Species	**D**	**N**	**% CV**	**n**
red-breasted nuthatch	3.24	232,731	97	11
red-tailed hawk	0.01	416	65	3
red-winged blackbird	0.21	15,430	83	21
ring-necked pheasant	0.1	7,417	100	5
rock pigeon	0.51	36,550	103	1
rock wren	2.04	146,668	30	84
ruby-crowned kinglet	0.53	38,161	66	8
sage sparrow	**13.6**	**975,760**	**21**	**248**
sage thrasher	**3.21**	**230,662**	**18**	**151**
sandhill crane	0	345	113	3
savannah sparrow	0.37	26,387	94	5
Say's phoebe	1.02	73,019	36	22
song sparrow	0.07	5,099	66	11
spotted towhee	0.41	29,576	70	20
Steller's jay	1.04	74,318	68	3
Townsend's solitaire	**0.02**	**1,377**	**101**	**1**
tree swallow	1.2	86,234	101	2
upland sandpiper	0.02	1,655	46	11
vesper sparrow	21.95	1,575,121	22	346
violet-green swallow	2.67	191,423	63	11
warbling vireo	0.1	6,976	84	1
western kingbird	0.01	930	52	2
western meadowlark	10.37	744,103	33	787
western tanager	0.15	10,907	62	6
western wood-pewee	0.35	25,393	98	7
white-crowned sparrow	0.38	27,429	98	3
white-throated swift	**0.06**	**4,393**	**110**	**3**
Wilson's snipe	0.08	6,086	104	3
yellow warbler	0.2	14,106	84	1
yellow-rumped warbler	9.42	676,377	21	16

Appendix D. NPS Certified Land Bird Species List along with species listed on six conservation lists (Nicholoff 2003, Keinath et al. 2003, Casey 2000, MTNHP & MT FWP 2008, USFWS 2008, and http://www.rmbo.org). Bolded species represent common breeding species in BICA.

Scientific Name	Common Name	WY Level I [1]	WYNDD SC [2]	MT Level I [3]	MTNHP & MT FWP 2009 [4]	USFWS 2008 [5]	PIF SRI [6]
Aeronautes saxatalis	**white-throated swift**						x
Selasphorus platycercus	broad-tailed hummingbird						
Selasphorus rufus	rufous hummingbird						x
Stellula calliope	**calliope hummingbird**		x			x	x
Accipiter cooperii	**Cooper's hawk**						
Accipiter gentilis	northern goshawk	x	x		x		x
Accipiter striatus	**sharp-shinned hawk**						
Aquila chrysaetos	**golden eagle**						
Buteo jamaicensis	**red-tailed hawk**						
Buteo lagopus	rough-legged hawk						
Buteo regalis	ferruginous hawk	x	x		x	x	x
Buteo swainsoni	Swainson's hawk	x				x	x
Circus cyaneus	**northern harrier**						x
Haliaeetus leucocephalus	bald eagle	x	x		x	x	
Pandion haliaetus	osprey						
Cathartes aura	**turkey vulture**						
Falco columbarius	merlin						
Falco mexicanus	**prairie falcon**						
Falco peregrinus	peregrine falcon	x	x		x	x	
Falco rusticolus	gyrfalcon						
Falco sparverius	**American kestrel**						
Ceryle alcyon	belted kingfisher						
Coccyzus americanus	yellow-billed cuckoo		x		x	x	
Coccyzus erythropthalmus	black-billed cuckoo		x		x		
Eremophila alpestris	**horned lark**						
Bombycilla cedrorum	**cedar waxwing**						
Bombycilla garrulus	Bohemian waxwing						

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Scientific Name	Common Name	WY Level I [1]	WYNDD SC [2]	MT Level I [3]	MTNHP & MT FWP 2009 [4]	USFWS 2008 [5]	PIF SRI [6]
Passerina amoena	**lazuli bunting**						x
Passerina cyanea	indigo bunting						
Pheucticus melanocephalus	black-headed grosbeak						
Certhia americana	brown creeper			x	x		
Cinclus mexicanus	American dipper						x
Corvus brachyrhynchos	**American crow**						
Corvus corax	**common raven**						
Cyanocitta cristata	blue jay						
Cyanocitta stelleri	Steller's jay						
Gymnorhinus cyanocephalus	**pinyon jay**				x		x
Nucifraga columbiana	**Clark's nutcracker**				x		x
Perisoreus canadensis	gray jay						
Pica pica	**black-billed magpie**						
Ammodramus savannarum	grasshopper sparrow				x		
Amphispiza belli	sage sparrow	x	x		x	x	
Calamospiza melanocorys	lark bunting						x
Chondestes grammacus	**lark sparrow**						
Junco hyemalis	**dark-eyed junco**						
Melospiza lincolnii	Lincoln's sparrow						
Melospiza melodia	**song sparrow**						
Passerculus sandwichensis	savannah sparrow						
Passerella iliaca	fox sparrow						
Pipilo chlorurus	**green-tailed towhee**						
Pipilo maculatus	**western spotted towhee**						
Plectrophenax nivalis	snow bunting						
Pooecetes gramineus	**vesper sparrow**						

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Scientific Name	Common Name	WY Level I [1]	WYNDD SC [2]	MT Level I [3]	MTNHP & MT FWP 2009 [4]	USFWS 2008 [5]	PIF SRI [6]
Spizella arborea	American tree sparrow						
Spizella breweri	**Brewer's sparrow**	x			x	x	x
Spizella pallida	clay-colored sparrow						
Spizella passerina	**chipping sparrow**						
Zonotrichia albicollis	white-throated sparrow						
Zonotrichia leucophrys	white-crowned sparrow						
Zonotrichia querula	Harris' sparrow						
Carduelis flammea	common redpoll						
Carduelis pinus	**pine siskin**						
Carduelis tristis	**American goldfinch**						
Carpodacus cassinii	**Cassin's finch**				x	x	x
Carpodacus mexicanus	**house finch**						
Coccothraustes vespertinus	evening grosbeak						
Leucosticte atrata	black rosy finch		x		x	x	x
Leucosticte tephrocotis	grey-crowned rosy finch						
Loxia curvirostra	red crossbill						x
Pinicola enucleator	**pine grosbeak**						
Hirundo pyrrhonota	**cliff swallow**						
Hirundo rustica	**barn swallow**						
Riparia riparia	**bank swallow**						
Stelgidopteryx serripennis	northern rough-winged swallow						
Tachycineta bicolor	tree swallow						
Tachycineta thalassina	**violet-green swallow**						
Agelaius phoeniceus	**red-winged blackbird**						

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Scientific Name	Common Name	WY Level I [1]	WYNDD SC [2]	MT Level I [3]	MTNHP & MT FWP 2009 [4]	USFWS 2008 [5]	PIF SRI [6]
Euphagus cyanocephalus	**Brewer's blackbird**						
Icterus bullockii	**Bullock's oriole**						
Molothrus ater	**brown-headed cowbird**						
Quiscalus quiscula	**common grackle**						
Sturnella neglecta	**western meadowlark**						
Xanthocephalus xanthocephalus	**yellow-headed blackbird**						
Lanius excubitor	northern shrike						
Lanius ludovicianus	**loggerhead shrike**		x		x	x	x
Dumetella carolinensis	gray catbird						
Oreoscoptes montanus	sage thrasher				x	x	
Toxostoma rufum	brown thrasher						
Anthus rubescens	American pipit						
Parus atricapillus	**black-capped chickadee**						
Parus gambeli	**mountain chickadee**						
Dendroica coronata	**yellow-rumped warbler**						
Dendroica petechia	**yellow warbler**						
Geothlypis trichas	**common yellowthroat**						
Icteria virens	**yellow-breasted chat**						
Mniotilta varia	black-and-white warbler						
Oporornis tolmiei	Macgillivray's warbler						
Seiurus aurocapillus	ovenbird						
Setophaga ruticilla	American redstart						
Vermivora celata	orange-crowned warbler						
Vermivora peregrina	Tennessee warbler						
Wilsonia pusilla	Wilson's warbler						
Passer domesticus	**house sparrow**						

Appendix D. NPS Certified Land Bird Species List along with species listed on six conservation lists (Nicholoff 2003, Keinath et al. 2003, Casey 2000, MTNHP & MT FWP 2008, USFWS 2008, and http://www.rmbo.org). Bolded species represent common breeding species in BICA. (continued)

Scientific Name	Common Name	WY Level I [1]	WYNDD SC [2]	MT Level I [3]	MTNHP & MT FWP 2009 [4]	USFWS 2008 [5]	PIF SRI [6]
Regulus calendula	ruby-crowned kinglet						
Regulus satrapa	golden-crowned kinglet						x
Sitta canadensis	**red-breasted nuthatch**						
Sitta carolinensis	white-breasted nuthatch						
Sturnus vulgaris	**European starling**						
Piranga ludoviciana	**western tanager**						
Catherpes mexicanus	canyon wren						
Cistothorus palustris	**marsh wren**						
Salpinctes obsoletus	**rock wren**						
Troglodytes aedon	**house wren**						
Catharus fuscescens	veery				x		
Catharus guttatus	hermit thrush						
Catharus ustulatus	**Swainson's thrush**						
Myadestes townsendi	**Townsend's solitaire**						x
Sialia currucoides	**mountain bluebird**						
Turdus migratorius	**American robin**						
Contopus borealis	olive-sided flycatcher			x		x	x
Contopus sordidulus	**western wood-pewee**						
Empidonax difficilis	western flycatcher						
Empidonax hammondii	Hammond's flycatcher						x
Empidonax minimus	**least flycatcher**						
Empidonax oberholseri	dusky flycatcher						x
Empidonax traillii	willow flycatcher					x	x
Sayornis saya	Say's phoebe						
Tyrannus tyrannus	**eastern kingbird**						
Tyrannus verticalis	**western kingbird**						

Appendix D. NPS Certified Land Bird Species List along with species listed on six conservation lists (Nicholoff 2003, Keinath et al. 2003, Casey 2000, MTNHP & MT FWP 2008, USFWS 2008, and http://www.rmbo.org). Bolded species represent common breeding species in BICA. (continued)

Scientific Name	Common Name	WY Level I [1]	WYNDD SC [2]	MT Level I [3]	MTNHP & MT FWP 2009 [4]	USFWS 2008 [5]	PIF SRI [6]
Tyrannus vociferans	Cassin's kingbird						
Vireo gilvus	**warbling vireo**						
Vireo olivaceus	red-eyed vireo						
Vireo solitarius	solitary vireo						
Colaptes auratus	**northern flicker**						
Melanerpes erythrocephalus	red-headed woodpecker				x		
Melanerpes lewis	Lewis' woodpecker		x		x	x	x
Picoides pubescens	downy woodpecker						
Picoides villosus	hairy woodpecker						
Sphyrapicus varius	yellow-bellied sapsucker						
Chordeiles minor	**common nighthawk**						
Phalaenoptilus nuttallii	common poorwill						
Aegolius acadicus	northern saw-whet owl						x
Asio flammeus	short-eared owl	x	x				x
Asio otus	long-eared owl						
Athene cunicularia	burrowing owl	x	x	x	x		
Bubo virginianus	**great horned owl**						
Nyctea scandiaca	snowy owl						
Otus asio	eastern screech-owl						
Otus kennicottii	western screech-owl						

[1] WY Level 1 = Wyoming Partners in Flight Level 1 Priority Species (Nicholoff 2003)

[2] WYNDD SC = Wyoming Natural Diversity Database Species of Concern (Keinath et al. 2003)

[3] MT Level 1 = Montana Partners in Flight Level 1 Priority Species (Casey 2000)

[4] MTNHP & MT FWP 2009 = Montana Animal Species of Concern (MTNHP & MT FWP 2009)

[5] USFWS 2008 = U.S. Fish and Wildlife Service Birds of Conservation Concern 2008 (USFWS 2008)

[6] PIF SRI = Partners in Flight Species of Regional Importance (http://www.rmbo.org)

Appendix E. Confirmed game bird species present in BICA according to NPS (2011) and Tom Easterly (pers. comm., 2012).

Common Name	Scientific Name	Common Name	Scientific Name
wood duck	*Aix sponsa*	tundra swan	*Cygnus columbianus*
northern pintail	*Anas acuta*	hooded merganser	*Lophodytes cucullatus*
American wigeon	*Anas americana*	common merganser	*Mergus merganser*
northern shoveler	*Anas clypeata*	red-breasted merganser	*Mergus serrator*
green-winged teal	*Anas crecca*	ruddy duck	*Oxyura jamaicensis*
cinnamon teal	*Anas cyanoptera*	common snipe	*Gallinago gallinago*
blue-winged teal	*Anas discors*	rock dove	*Columba livia*
mallard	*Anas platyrhynchos*	mourning dove	*Zenaida macroura*
gadwall	*Anas strepera*	chukar	*Alectoris chukar*
lesser scaup	*Aythya affinis*	ruffed grouse [1]	*Bonasa umbellus*
redhead	*Aythya americana*	sage grouse [2]	*Centrocercus urophasianus*
ring-necked duck	*Aythya collaris*	blue grouse [1]	*Dendragapus obscurus*
greater scaup	*Aythya marila*	wild turkey	*Meleagris gallopavo*
canvasback	*Aythya valisineria*	gray partridge	*Perdix perdix*
Canada goose	*Branta canadensis*	ring-necked pheasant	*Phasianus colchicus*
bufflehead	*Bucephala albeola*	sharp-tailed grouse [2]	*Tympanuchus phasianellus*
common goldeneye	*Bucephala clangula*	sandhill crane	*Grus canadensis*
Barrow's goldeneye	*Bucephala islandica*	American coot	*Fulica americana*
snow goose	*Chen caerulescens*	sora	*Porzana carolina*
oldsquaw	*Clangula hyemalis*	Virginia rail	*Rallus limicola*

[1] BICA does not contain habitat suitable for this species, although it has been documented in the park before

[2] This species may potentially be in the park, but WGFD is unaware of any documentation

Appendix F. Macroinvertebrate taxa list for BICA (NPS 2011).

Taxa		**Notes**
Non-Insects		
Phylum Porifera (freshwater sponges)		
Class Turbellaria (flatworms)		
Phylum Nematoda (roundworms)		
Subclass Oligochaeta (segmented worms)		
Subclass Hirudinea (leeches)		
	Family Erpobdellidae	
	Family Glossiphoniidae	
Class Bivalvia		
	Sphaerium sp.	
Class Gastropoda		
	Family Lymnaeidae	
	Lymnaea sp.	Below dam
	Potamopyrgus antipodarum	Below dam
	Physa sp.	
	Physella sp. (snail)	
Subclass Acari (water mites)		
	Hydrachnidia	
Class Branchiopoda (fairy shrimp)		
Class Ostracoda (seed shrimp)		
	Subclass Podocopa	
Subclass Copepoda		
Order Isopoda		
	Caecidotea sp.	
Order Amphipoda		
	Crangonyx sp.	
	Gammarus sp.	
	Hyalella sp.	
Order Decopoda		
Subclass Collembolla (springtails)		
Insects		
Order Odonata		
	Argia sp. (damselfly)	
	Ophiogomphus sp.	
Order Ephemeroptera (mayflies)		
	Ameletus sp.	Layout Creek
	Acentrella insignificans	
	Family Baetidae	
	Baetis bicaudatus	
	Baetis tricaudatus	
	Camelobaetidius sp.	
	Camelobaetidius warreni	Bighorn River
	Diphetor hageni	Layout Creek
	Fallceon quilleri	Bighorn River
	Cercobrachys sp.	
	Drunella doddsi	
	Ephemerella excrusians	
	Cinygmula sp.	
	Mccaffertium sp.	
	Tricorythodes minutus	
	Neochoroterpes sp.	Bighorn River
	Paraleptophlebia sp.	
Order Plecoptera (stoneflies)		
	Family Capniidae	
	Family Chloroperlidae	
	Sweltsa sp.	
	Malenka sp.	
	Zapada cinctipes	
	Hesperoperla pacifica	

Appendix F. Macroinvertebrate taxa list for BICA (NPS 2011). (continued)

Taxa		Notes
	Isoperla sp.	
Order Trichoptera (caddisflies)		
	Brachycentrus americanus	
	Brachycentrus occidentalis	
	Micrasema sp.	
	Culoptila sp.	
	Cheumatopsyche sp.	
	Hydropsyche sp.	
	Agraylea sp.	Crooked Creek
	Hydroptila sp.	
	Lepidostoma sp.	
	Oecetis sp.	
	Hesperophylax sp.	
	Family Limnephilidae	
	Dolophilodes sp.	
	Rhyacophila brunnea/vemna group	
Order Hemiptera (true bugs)		
Order Lepidoptera (aquatic moths)		
	Petrophila sp.	
Order Megaloptera (dobsonfly)		
Order Coleoptera (beetles)		
	Helichus sp.	
	Postelichus sp.	
	Family Dytiscidae	
	Subfamily Hydroporinae	
	Dubiraphia sp.	
	Heterlimnius sp.	
	Microcylloepus sp.	
	Narpus sp.	
	Optioservus sp.	
	Haliplus sp.	
	Family Hydrophilidae	
Order Diptera (true flies)		
	Subfamily Ceratopogoninae	
	Family Dixidae	
	Dixa sp.	
	Chelifera/Metachela sp.	
	Hemerodromia sp.	
	Limnophila sp.	
	Ormosia sp.	
	Family Muscidae	
	Limnophora sp.	
	Pericoma sp.	Below dam
	Ptychoptera sp.	
	Simulium sp.	
	Caloparyphus sp.	Below dam
	Dicranota sp.	
	Hexatoma sp.	
	Tipula sp.	
Order Diptera, Family Chironomidae (midges)		
	Alatanypus sp.	
	Apedilum sp.	
	Brillia sp.	
	Cladotanytarsus sp.	
	Corynoneura sp.	
	Cricotopus sp.	
	Cryptochironomus sp.	
	Diamesa sp.	

Appendix F. Macroinvertebrate taxa list for BICA (NPS 2011). (continued)

Taxa		Notes
	Dicrotendipes sp.	
	Epoicocladius sp.	
	Eukiefferiella sp.	
	Limnophyes sp.	
	Micropsectra sp.	
	Microtendipes sp.	
	Orthocladius Complex	
	Pagastia sp.	
	Parakiefferiella sp.	
	Paramerina sp.	
	Parametriocnemus sp.	
	Paratanytarsus sp.	
	Parorthocladius sp.	
	Pentaneura sp.	
	Phaenopsectra sp.	
	Polypedilum sp.	
	Potthastia longimana group	
	Pseudosmittia sp.	
	Rheocricotopus sp.	
	Rheotanytarsus sp.	
	Stilocladius sp.	Layout Creek
	Tanytarsus sp.	
	Thienemanniella sp.	
	Tvetenia bavarica group	
	Virgatanytarsus sp.	

Appendix G. Viewscape analysis methods, written by Melanie Myers.

To ensure the baseline viewshed analysis was as useable as possible, the NRCA team decided to look at multiple components of the landscape that could affect scenic views. These components include:

• Development, including roads and power-lines, and land ownership visible from each observation point.

• Housing density that can be seen from each observation point.

The components of the landscape listed above are not necessarily bad (negative??), because the park is a Recreation Area, some infrastructure and development have to be expected. A possible question that could be answered from further research is how much development is too much. This analysis is only to show what can be seen from each observation point so that future viewsheds can be compared.

Once the observation points were finalized an Offset A of 1.68 m (5.5 ft) was added to each observation point's attribute table. This simulates the average height of a person during the viewshed analysis. In order to accurately assess where the power line was visible from the observation points, the following steps were taken in ArcGIS to modify the Digital Elevation Data used in the viewshed (Model 1):

Workspace: At each stage in this process results were projected in USA_Contiguous_Albers_Equal_Area_Conic_USGS_version and BICA_10m_usgs.tiff was used to snap to raster and for the cell size in the following process steps.

- DEM was downloaded from http://seamless.usgs.gov/ ; re-projected and named BICA_10m_usgs.tiff.
- Ran a viewshed using the observation points and BICA_10m_usgs.tiff. The resulting viewshed is a general viewshed that does not include the powerline height, called Viewshed_Off _A.tiff.
- Performed a Buffer operation on the power line shapefile "Power_line_nad83.shp" called "Powerln_75mBuff.shp". (chose the buffer of 75 meters so the cells added to the visible area in the viewshed could be seen at the extent of the maps.)
- Added a "Height" attribute of 21.336 meters to "Powerln_75mBuff.shp".
- Converted "Powerln_75mBuff.shp" to a Raster using the "Height" attribute as the value field, making sure the output coordinate was correct, set the snap raster, and cell size. Named raster Powln_Raster.tiff.
- Performed a Raster Calculation and added Powln _Raster.tiff to Bica_10m_usgs.tiff. Set output coordinate, snap raster, and cell size. Called raster rastercalc.tiff.
- Mosaicked rastercalc.tiff and BICA_10m_usgs.tiff. Set output coordinate, snap raster, and cell size. Called raster Mosaic_10mDEM_Pwln.tiff. This creates a DEM with the power line elevation included.
- Performed another viewshed with Mosaic_10mDEM_Pwln.tiff and each observation point, creating a viewshed called Viewshed_w_Powrln.tiff that includes the power line height. Adding the power line to the DEM creates a slight problem, the power line height

acts like a wall of cells 21.336 meters high in the viewshed analysis, this creates some "shadowing" and "blocking" of cells that should be seen because the power line is not a solid object. To fix this process I extracted the "visible areas" of Viewshed_w_Powrln.tiff that overlap Powerln_75mBuff.shp, explained in the next step.

- Extracted by mask Viewshed_w_Powrln.tiff with Powerln_75mBuff.shp and called it View_Power_Extract.tiff.
- Mosaicked View_Power_Extract .tiff with Viewshed_Off _A.tiff. This added only the visible areas directly affected by the power line to the viewshed. Called raster Viewshed_w_Powrln.tiff.

I used ESRI ArcGIS v10 software to add information to the attribute tables, and make the viewshed maps. I used Buffer, Raster Calculator, and Mosaic tools and Spatial Analyst extension to add the power line elevation to the DEM and create the viewsheds.
ESRI ArcGIS v10 Spatial Analyst Tool inputs:
Input Raster: Mosaic_10mDEM_Pweln.tiff
Input Shapefile: Shapefile with all six Observation points.
Eventually ran the viewshed process above for each of the Observation Points: Four Winds Overlook, Lockhart Ranch, Devil Canyon Overlook, Mustang Flats, Sullivan's Knob, and Stateline pullouts, to get individual viewsheds for maps.

To create the tables: I converted Viewshed_w_Powrln.tiff to a shapefile called View_AOI.shp. I did not keep analysis in rasters at this point because every time I tried to extract data with AOI I got very "pixely" outputs that would not give an accurate area calculation.

For the Land Ownership area calculation: I used the View_AOI.shp as an input for the ProtectedAreaDatabaseUS_Metrics tool in the NPScape NPScape_ConservationStatusTools tool set. This tool extracts Land Ownership data from PAD-US database. Called output shapefile Land_Own_Extract. Then exported a summary with the attributes wanted for the table.

For the Housing Density area calculation: Intersected the View_AOI.shp with the Housing density shapefile. Called new shapefile House_Density_Extract. Then exported a summary with the attributes wanted for the table.

Appendix H. Plant species observed in BICA spring microhabitats (Schmitz 2009).

Species	Species	Species
Achillea millefolium	*Galium boreale*	*Salix exigua*
Alyssum alyssoides	*Gaura coccinea*	*Sarcobatus vermiculatus*
Arctium minus	*Glyceria striata*	*Senecio sphaerocephalus*
Artemisia cana	*Glycyrrhiza lepidota*	*Shepherdia argentea*
Asclepias speciosa	*Grindelia squarrosa*	*Sisyrinchium idahoense*
Bassia sieversiana	*Gutierrezia sarothrae*	*Solidago missouriensis*
Berula erecta	*Gymnostomum aeruginosum*	*Solidago* spp.
Betula occidentalis	*Heterotheca villosa*	*Sonchus* spp.
Bromus inermis	*Hypnum revolutum*	*Sporobolus airoides*
Bromus tectorum	*Iris missouriensis*	*Sullivantia hapemannii*
Bryum gemmiparum	*Iva axillaris*	*Symphoricarpos occidentalis*
Bryum pseudotriquetrum	*Juncus balticus*	*Syntrichia ruralis*
Camelina microcarpa	*Juncus confusus*	*Tamarix chinensis*
Cardaria pubescens	*Juncus ensifolius*	*Taraxacum officinale*
Carex atrata	*Juncus mertensianus*	*Toxicodendron rydbergii*
Carex aurea	*Juncus parryi*	*Typha latifolia*
Carex interior	*Juniperus osteosperma*	*Urtica dioica*
Carex nebrascensis	*Juniperus scopulorum*	*Veronica americana*
Carex pellita	*Luzula parviflora*	*Veronica anagallis*
Carex scopulorum	*Maianthemum stellatum*	*Viola adunca*
Centaurea repens	*Marchantia polymorpha*	
Chenopodium	*Medicago sativa*	
Cicuta bulbifera	*Mentha arvensis*	
Cirsium arvense	*Najas guadalupensis*	
Cirsium vulgare	*Nasturtium officinale*	
Clematis ligusticifolia	*Palustriella commutate*	
Conardia compacta	*Phragmites australis*	
Cornus sericea	*Plantanthera* spp.	
Cratoneuron filicinum	*Poa pratensis*	
Descurainia pinnata	*Populus acuminata*	
Didymodon tophaceus	*Populus angustifolia*	
Distichium inclinatum	*Populus deltoides*	
Elaeagnus angustifolia	*Prunus virginiana*	
Eleocharis palustris	*Pseudoleskeella tectorum*	
Elymus spicatus	*Ribes aureum*	
Equisetum laevigatum	*Ribes oxycanthoides*	
Ericameria nauseosa	*Rosa sayi*	
Festuca arundinacea	*Rosa woodsii*	
Fissidens grandifrons	*Rumex salicifolius*	
Funaria hygrometrica	*Salix amygdaloides*	

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National Park Service
U.S. Department of the Interior

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