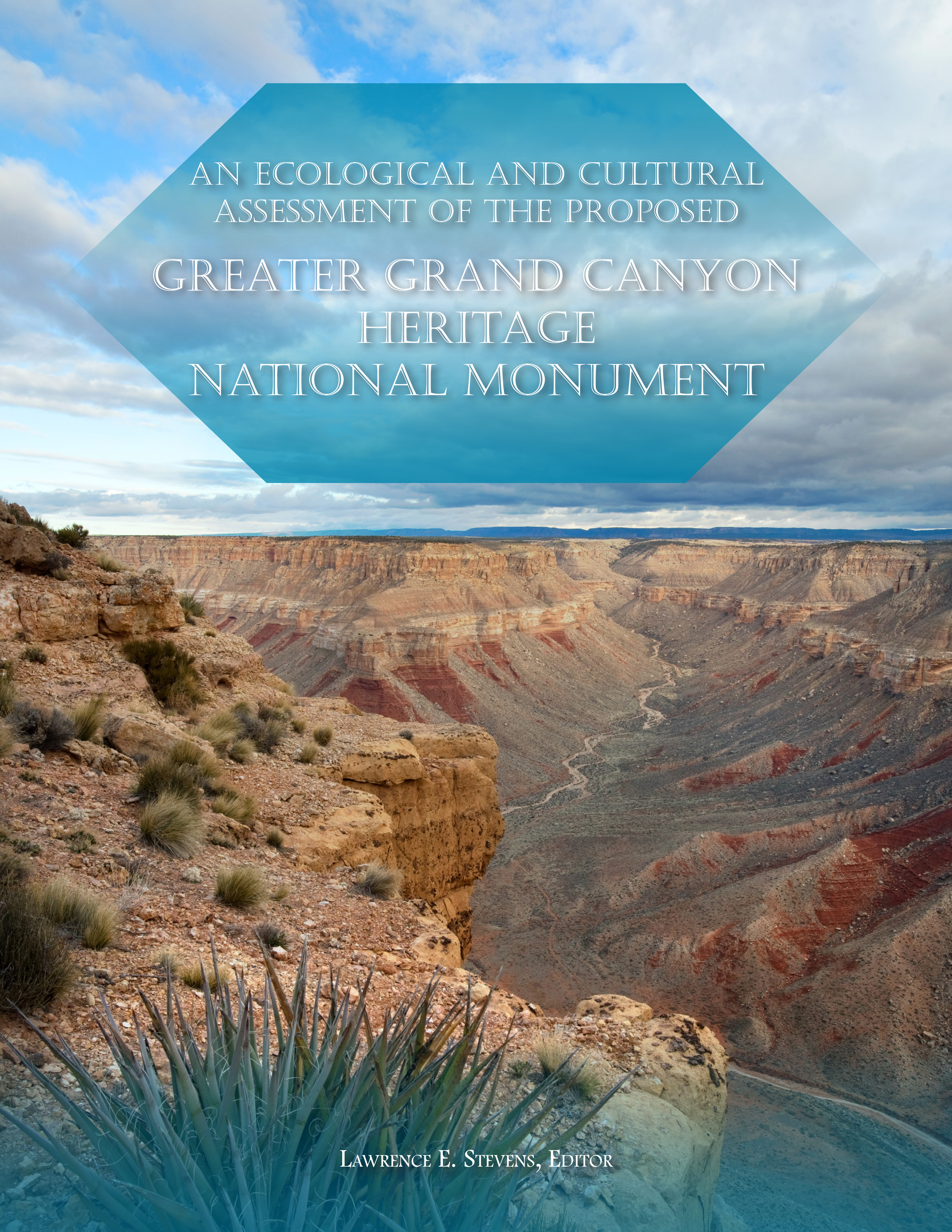
An Ecological and Cultural Assessment of the Proposed

Greater Grand Canyon Heritage National Monument



Lawrence E. Stevens, Editor

The Natural and Human History of the Proposed

Greater Grand Canyon Heritage National Monument

Lawrence E. Stevens, Editor

ACKNOWLEDGEMENTS

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A VAST, REMOTE, FORESTED LANDSCAPE

The proposed Greater Grand Canyon Heritage National Monument (GGCHNM) includes the Kaibab Plateau, House Rock Valley, and the southern part of the Kanab Creek drainage, as well as a portion of the Coconino Plateau immediately south of Grand Canyon National Park. The proposed monument area spans Grand Canyon and is a vast, arid, largely forested landscape on the southwestern Colorado Plateau. GGCHNM is bordered to the west by the Shivwits Plateau, and to the east by the Vermilion Cliffs. The Utah border and Highway 89A create the northern boundary. The eastern margin of the GGCHNM at the edge of Marble Canyon is distinguished by the enormous East Kaibab Monocline, a grand warping of the Earth's crust that elevates the North Rim of Grand Canyon more than 800 m above the South Rim. The GGCHNM then steps westward down an ecological transition, or ecotone, across a profound geological and biological boundary in one of the world's most iconic landscapes. This western ecotone frames the transition between the Colorado Plateau and the southern US desert biomes.

This report was prepared by scientists and researchers of the Museum of Northern Arizona and presents a detailed analysis of the existing physical, biological, and socio-cultural information on the GGCHNM region. This effort augments excellent syntheses by individual federal and state managing agencies including: the U.S. Bureau of Land Management (BLM; 1990, 1992); Arizona Game and Fish Department (AGFD; BLM and AGFD 1997); U.S. National Park Service (NPS; 1981); and the U.S. National Forest Service (USFS; 2012). We strive to incorporate their reports and scientific studies over the past century into a single overview of the GGCHNM region.

GEOGRAPHY AND CONTEXT

Most of the 6,877 km^2 GGCHNM lies at elevations between 1,500 and 2,700 m. Seen from the air, the Kaibab Upwarp appears as a domed surface, elongated north-south, sloping abruptly up from the east, and gently down to the west. Erosion and dissection across the Kaibab Monocline characterizes the northern portion of GGCHNM. Along its western side, north of the Park boundary, the monument area includes most of the Kanab Plateau and a section of the Uinkaret Plateau east of the Hurricane Cliffs and the Hurricane Fault. To the east of the Kaibab Plateau, GGCHNM includes lands in House Rock Valley and the northern Marble Platform, wrapping around the base of the Paria Plateau and abutting the Vermillion Cliffs National Monument. The GGCHNM region is remote, in large part due to its topographic isolation, its location on the Arizona Strip between the Colorado River and Utah, and because access into the region is seasonal or weather dependent and largely restricted to Highways 89A and 67 and several major dirt roads.

The GGCHNM encompasses public lands, most of it presently administered by the Kaibab National Forest (KNF), BLM, AGFD and NPS. Formal designation and permanent protection for the proposed monument would allow for continued public access, traditional lifeways, rights of way, sightseeing, hiking, wildlife observation, birding, hunting, fishing, and many other activities, including traditional Tribal access and uses. Permanently protecting this area will help conserve and restore grasslands and old growth forests, and protect important archaeological sites, native wildlife, springs and wetlands, endemic species, and wildlife migration routes. The GGCHNM may be jointly managed by the USFS and the BLM. The USFS currently manages nine national monuments. Although their histories are sometimes complex, four are the result of Presidential proclamations and five are congressionally designated.

SCIENCE VALUES

The information summarized here, and presented in detail in the full report, identifies ten outstanding characteristics of the GGCHNM region, including: 1) its position encompassing the local watershed or drainage surrounding Grand Canyon and the ecotonal transitional boundary from the Colorado Plateau to the Basin and Range Geologic Provinces; 2) its function as a remarkable geohydrological laboratory, with unique springs, seeps, natural ponds and source of headwaters for some of the last remaining pristine streams in the Southwest, 3)its paleoecological significance as a landscape demonstrating vegetation responses to global climate change over the past 50,000 years along a world-class stepped ecotone at the edge of Grand Canyon; 4) its value as a biodiversity hotspot for endemic species and 5) refuge for sensitive and game species; 6) its large north-south escarpment, which serves as a corridor for migratory raptors and other species; 7) its scientific and management value as a study area for the implementation of restoration projects for wildlife populations and landscapes; 8) the existence of artifacts and sites that date back nearly 8000 years; 9) its place in the tumultuous recent human history of the Grand Canyon region; and 10) its vast, remote, little-developed character that provides tremendous scenic, recreational and dark skies value, while acting as a natural buffer for Grand Canyon National Park in the face of human development. As a result of this comprehensive, science-based analysis, it is clear that the national monument proposal being considered is well supported in this remarkable, iconic landscape. The ten outstanding characteristics are described below, along with the importance of landscape connectivity and the protection of the Grand Canyon's watershed and surrounding lands.

Aerial view looking across the Kaibab Monocline and House Rock Valley with the Vermilion Cliffs and Paria Plateau in the distance. Photo ©Kristen M. Caldon.

Unique Geographical Significance

The proposed Greater Grand Canyon Heritage National Monument (GGCHNM) includes the Kaibab Plateau, House Rock Valley, and the southern part of the Kanab Creek drainage, as well as a portion of the Coconino Plateau immediately south of Grand Canyon National Park, spanning the Grand Canyon and forming its proximal watershed. Bordered on the west by the Shivwits Plateau, to the east by the Vermilion Cliffs, and on the north by Highway 89A and the Utah state line, the proposed monument captures a piece of western geography that has shaped the distribution of humans and wildlife across the southwest for millennia.

The GGCHNM's geographical significance is also due in large part to the unique geological activity that resulted in the enormous East Kaibab Monocline, which elevates the North Rim of Grand Canyon as much as 800 m above the South Rim and the geological and biological western ecotone that frames the transition between the Colorado Plateau and the southern US deserts. Influencing processes from the movement of water to the evolution of native species, this geographical and geological transition zone is of significant scientific value.

Hydrogeology

The GGCHNM region spans one of the most profound geological features in the United States, the chasm of Grand Canyon. The exposure of Colorado Plateau strata reveals not only the vastness of time that has transpired over Earth's history, but also provides a detailed look into the geohydrology that supports the aquifers and hydrologic cycle of this arid region. As such, the GGCHNM is a geohydrological laboratory, which can be studied to better understand how water moves through the Earth and how aquifers function, especially karstic systems. While the proposed GGCHNM does not, itself, contain many flowing streams, it protects the headwaters of a large number of pristine streams and contains numerous ecologically and culturally significant springs, seeps, and natural ponds. This landscape also provides recharge to regional aquifers that contribute more than 5% of the base flow of the Colorado river.

Mineral resources are relatively few in the GGCHNM, except for uranium, which is deposited in many breccia pipes throughout the region. The present temporary ban on new mining claims is scheduled to end in 16 years, although some mining in the region is underway. The question of whether to allow uranium mining on the periphery of Grand Canyon remains an important social question, one that warrants careful consideration.

Climate Change and Ecotone Ecology

A remarkable paleoecological transformation has occurred in the GGCHNM over the past 50,000 years. The western margin of the GGCHNM roughly coincides with the boundary between the Sonoran/Mojave/Great Basin floristic provinces to the west, with the Maderan province to the south, and the Intermountain province to the

A panoramic view looking south to the lower plateau. Elevation and vegetation change dramatically from north to south in the GGCHNM. Photo by Kristen Caldon.

northeast. Analysis of ancient packrat middens and cave deposits has revealed that the pinyon-juniper treeline rose 914 m upslope in less than 7,000 years during the Pleistocene-Holocene transition, as a warmer, drier climate developed. These environmental shifts resulted in the mixing of plant species from the surrounding ecosystems and biomes. Environmental and floristic changes, coupled with the arrival of early humans, resulted in the extinction of the Pleistocene megafauna – elephants, camels, mountain goats, large predators, and giant birds that roamed the plateaus and lowlands, prior to natural desertification. On-going concerns over how ecosystems will function in response to global climate changes, can be examined through space-for-time studies across the elevation and aspect gradients that are so abundantly expressed in the GGCHNM. Thus, the region is a unique and critically important natural laboratory in which to study and understand these changes.

A Biological and Evolutionary Hotspot

Desert and plateau springs, deep and enormous karst cave systems, and old growth coniferous forests provide refugia and make the Kaibab an important biological hotspot. The Forest Service manages more than 200 springs on the North Kaibab, many of which harbor rare and sometimes unique life forms. For example, the springs and habitats in the North Canyon drainage support at least 6 rare or endemic species of plants and invertebrates, as well as endangered Apache trout. Many Forest springs have been altered by human activities, but can be easily restored. These springs and seeps are hot spots for biodiversity: stoneflies, beetles, and various amphibians require springs wetland habitats.

A Refuge for Sensitive and Game Species

The GGCHNM region supports at least 1500 plant species, an extraordinary but poorly documented entomofanua with several endemic species, one endangered fish species, 6 amphibian species, more than a dozen reptile species, 112 bird species, and 79 mammal species. Several dozen Kaibab plant and animal species are rare or endemic, and are species of concern to the State of Arizona, the U.S. Fish and Wildlife Service (USFWS), the USFS, or other agencies, Tribes, and organizations. The extent of migratory and upland species using the GGCHNM and its role as a corridor, flyway, and refuge is critical to the persistence of those many iconic species and populations.

An Important Migratory Corridor

The long, north-south aligned escarpment of the East Kaibab Monocline has been identified as one of the primary hawk migratory flyways in the Southwest. Cliffs such as these provide migratory pathways for hawks, eagles, and other species, and are well-documented, with more than 20 years of autumn raptor monitoring data available from Hawk Watch International. A large number of raptors migrate through southern Utah and use upwardly-rising air currents that develop as daytime mountain winds along cliff lines. Raptor densities often exceed 30 birds/hr. These observations indicate that the use of escarpments by raptors is commonplace. Continued monitoring is beginning to provide trend assessment capacity, but thorough surveys continue to be needed to improve resolution of the extent, timing and daily variability of raptor migration along the East Kaibab Monocline and across Grand Canyon. The North Kaibab region also provides an important primary movement corridor for Desert Mule Deer, and likely other large mammals, such as Desert Bighorn Sheep, and Mountain Lion from lowland to upland habitats.

Population and Landscape Restoration Ecology

Restoration ecology is being explored and implemented in the region through several different projects. 1) USFS has undertaken springs and forest rehabilitation projects. 2) Endangered California Condors have been released from a site on the Vermilion Cliffs near Marble Canyon, with more than 75 birds presently flying. 3) Pronghorn and Bighorn Sheep population restoration efforts have increased the herd and flock sizes. 4) Non-native tamarisk, an invasive woody tree, has been removed from desert springs along Kanab Creek, and the impacts of tamarisk leaf beetles are being examined throughout northern Arizona. The region has enormous potential for restoration projects to restore old growth forests and their ecological functions. These population and ecosystem management activities demonstrate that the GGCHNM region is an extraordinary natural laboratory in which to test and apply the principles of conservation and restoration ecology.

Archaeology

Much of the current understanding of GGCHNM region archaeology is based on small-scale, superficial surveys, rather than on broad or detailed assessments. However, existing research has revealed Paleoindian artifacts from the region dating to perhaps >6,000 BC; quarries, campsites and chipping areas dating from the Archaic period (ca. 2500 to 300 BC), as well as numerous house sites dating to the Basketmaker II to Pueblo III periods (ca. AD 500-1150); and Southern Paiute occupation (ca. AD 1250-1880). Pictograph sites, caves (including some with feathered arrowshafts, sandals, and woven baskets) and rockshelters containing elaborate rock art have been discovered. Preliminary data suggested that this region was primarily used for seasonal hunting and gathering, with summertime horticulture and habitations. Conservation and further inventory and study of these sites and remains will elucidate the complex relationships between early humans in the GGCHNM and Grand Canyon regions. These sites and remains are considered by contemporary American Indians as significant cultural properties.

Exploration and Settlement History

The color and harshness of the GGCHNM region is strongly reflected in its exploration and settlement history. Though the focal point of the region is the Canyon itself, a large portion of its history and development took place in the proposed GGCHNM. Expeditions led by European explorers resulted in the first documentation and interaction with Grand Canyon by those outside American Indian communities. As new settlers moved west from eastern America, early mountain men and pioneers created and maintained trails and villages throughout the proposed monument landscape. Interactions, both peaceful and violent, between American Indian tribes and European settlers influenced the politics and use of the lands and waters in the region. Industries such as cattle operations, mining, and timber harvest popped up, all of which played an important role in the development of local economies. The GGCHNM is a reflection of the dynamic and ever-shifting understanding of the role and influence of human development on the Grand Canyon region, all of which is of great historical importance for all Americans.

A Vast, Scenic Landscape that Protects Grand Canyon

The GGCHNM region is a truly vast and largely undeveloped landscape, made more remote and inaccessible due to its geographical features. The Plateau, its escarpment margins, and the surrounding lands, have exceptional regional and global scenic, recreational, scientific, and cultural value. Protection of this region will provide a better buffer from the impacts of human development and climate change, helping to protect Grand Canyon from the onslaught of environmental disruption that so greatly threatens the ecological integrity of the Southwest.

SUMMARY

This landscape analysis indicates that significant geological, biological and human history features and processes exist in the GGCHNM region, and additional research is likely to contribute substantial information to understanding the processes and impacts of geological, biogeographic, and global environmental change. The objects, features, and scientific opportunities mentioned herein, coupled with the overall high ecological integrity of most of the landscape, its low human population density and development, and few extractable resources, are values that contribute to the national significance of the GGCHNM.

Protection of these distinctive characteristics of the GGCHNM region will also buffer Grand Canyon National Park from the impacts of rapid population expansion in southern Utah and Nevada, as well as threats just outside the Park. In addition, the proposed National Monument will provide better landscape linkage among the region's Wilderness Areas, protect prominent north-south migration routes, springs, caves, the Kanab Creek drainage, old growth forest stands on the Kaibab Plateau, and sensitive and game populations and their habitats. Much remains to be learned about the GGCHNM region, and future inventories and studies are likely to substantially increase the list of species, identify important, as yet unrecognized, archeological sites, ecological processes, and insights into how climate changes affect or are buffered in complex landscapes. Such research opportunities are only likely to further strengthen the rationale for preserving this geologically, biologically and anthropologically outstanding landscape.

Chapter 1

Overview of the Greater Grand Canyon Heritage National Monument

A Vast, Remote Forested Landscape

The proposed Greater Grand Canyon Heritage National Monument (GGCHNM) includes the Kaibab Plateau, House Rock Valley, and the southern part of the Kanab Creek drainage, as well as a portion of the Coconino Plateau immediately south of Grand Canyon National Park (Fig. 1.1). The 6,877 km^2 proposed monument landscape surrounds Grand Canyon and is a vast, arid, largely forested lanscape on the southwestern Colorado Plateau. GGCHNM is bordered to the west by the Shivwits Plateau, and to the east by House Rock Valley, the Vermilion Cliffs, and Marble Canyon. The Utah border and Highway 89A creates the northern boundary. The eastern margin oat the edge of Marble Canyon is defined by the enormous East Kaibab Monocline, a grand upwarping of the Earth's crust that elevates the North Rim of Grand Canyon more than 800 m above the South Rim. To the west, GGCHNM steps down an ecological transition, or ecotone, across a profound geological and biological boundary in one of the world's most iconic landscapes.This western ecotone frames the transition between the Colorado Plateau and the southern US desert biomes.

This report was prepared by scientists and researchers of the Museum of Northern Arizona and presents a detailed analysis of the existing physical, biological, and socio-cultural information on the GGCHNM region. This effort augments excellent syntheses by individual federal and state managing agencies including: the BLM (1990), 1992); Arizona Game and Fish Department (AGFD; BLM and AGFD1997); U.S. National Park Service (NPS; 1981); and the U.S. National Forest Service (USFS; 2012), incorporating those data with additional scientific studies over the past century to provide an overview of the GGCHNM region. We summarize scientific information on the region's geography, geology, biology, archaeology, and history. We describe the natural and cultural resources of the region and surrounding lands. This region holds great potential for further scientific study and understanding of regionally and globally important issues related to ecosystem ecology and stewardship, elevation gradients, and climate change.

Ten characteristics may warrant consideration of the GGCHNM region. These include: 1) its position encompassing the local watershed or drainage surrounding Grand Canyon and the ecotonal transitional boundary from the Colorado Plateau to the Basin and Range Geologic Provinces; 2) its paleoecological significance as an ecoregion that has responded to dramatic climate change over the past 50,000 years, producing a world-class stepped ecotone landscape; 3) its biological diversity, particularly life found in rare hotspot habitats (i.e., springs, caves, old growth forests, and desert streams); 4) its function as a refuge supporting species of concern (i.e., endemic, endangered species and game species); 5) its several large escarpments, which serve as a migratory corridor for raptors and other species; 7) its scientific and management value as a study area for the implementation of restoration projects for wildlife populations and landscapes; 8) the existence of artifacts and sites that date back nearly 8000 years; 9) its place in the tumultuous recent human history of the Grand Canyon region; and 10) its vast, remote, little-developed character that provides tremendous scenic, recreational, and dark skies value, while acting as a natural buffer for Grand Canyon National Park. We discuss the regional and national scientific and socio-cultural significance of these characteristics, as well as the region's scenic values, its present ecological integrity, its population density and its development history.

Fig. 1.1 Map of the proposed Grand Canyon Heritage National Monument in northern Arizona.

CHAPTER 2

GEOGRAPHY AND CLIMATE

LARRY STEVENS AND JEFF JENNESS

Plateau Forests, Escarpments, Canyons, and Low Deserts

Most of the 6,877 km^2 GGCHNM lies at elevations between 1,500 and 2,700 m. Seen from the air, the Kaibab Upwarp appears as a domed surface, elongated north-south, rising abruptly up from the east, and gently subsiding down to the west. Erosion and dissection across the Kaibab Monocline characterizes the northern portion of GGCHNM. Along its western side, north of the Park boundary, the monument area includes most of the Kanab Plateau and a section of the Uinkaret Plateau east of the Hurricane Cliffs and the Hurricane Fault. To the east of the Kaibab Plateau, GGCHNM includes lands in House Rock Valley and the northern Marble Platform, wrapping around the base of the Paria Plateau and abutting Vermilion Cliffs National Monument.

The GGCHNM region is remote, in large part due to its topography and its location on the Arizona Strip north of the Colorado River, and because access into the region is seasonal and largely restricted to Highway 89A and several dirt roads. From the east, Highway 89A runs up the East Kaibab Monocline to Jacobs Lake. On the west, access is limited to the Fredonia Road (FS Rt. 22), with a maze of smaller forest roads that work west to the headwaters of Kanab Creek. South of Grand Canyon, primary access is provided by Highway 64 from Cameron to the South Rim, and Highways 180 and 64 south to Williams and Flagstaff, 70-80 miles away. Many dirt roads traverse the pinyon-juniper and grasslands that dominate the northern Coconino Plateau.

Land Management

The GGCHNM is administered by the National Forest Service (Kaibab National Forest, KNF), the Bureau of Land Management (the Arizona Strip region, BLM), and the Arizona Game and Fish Department (AGFD; National Park Service 1981; U.S. Bureau of Land Management 1990, 1992). Nationally, the Forest Service manages several national monuments, four of which were designated through acts of Congress, and two of which were designated by presidential proclamation (https://utah.sierraclub.org/content/grand-canyon-watershed-national-monument). Formal designation and permanent protection for the GGCHNM will allow for traditional lifeways, continued public access for sightseeing, hiking, wildlife observation, birding, hunting, fishing, and many other activities, including traditional Tribal access and uses. Permanent protection will allow for continued research opportunities and conservation of natural resources such as old growth forests and grasslands, important archaeological sites, native wildlife, springs and wetlands, and wildlife migration routes. The monument would be jointly managed (like Grand Canyon-Parashant National Monument) by the Forest Service and the Bureau of Land Management. The Forest Service currently manages nine national monuments.

Several other federal and state agencies have jurisdiction over some natural and economic resources in the GGCHNM. The USFWS advises other federal agencies regarding protection of threatened and endangered species. Federal jurisdiction of the GGCHNM landscape is authorized under the Federal Land Policy and Management Act of 1976. The Kaibab Band of Paiute Indians occupies the largest nearby reservation, which lies just north of the proposed monument. They, the Shivwits and other Southern Paiute bands, as well as, the Hopi and Zuni Tribes and the Navajo Nation claim cultural affiliation with the north side of the landscape. South of Grand Canyon, the Havasupai, Hopi, Hualapai, Navajo, and Zuni claim cultural affiliation. State and private land ownership is limited, with the largest allotment holders in the region being the Grand Canyon Trust on the North Rim and the Babbitt Ranches south of Grand Canyon. The largest nearby communities are Fredonia, Kanab, Colorado City, and Hurricane on the north side, and Tusayan, and Grand Canyon on the south, with the larger cities of St. George, Page, Williams, and Flagstaff lying outside the region (Fig. 1.1).

Weather and Climate

The climate of the GGCHNM is continental and arid, and is variable and often harsh. Low elevations (below 1,000 m) have mean annual temperatures of 17-19° C, with daily minimum and maximum temperatures normally fluctuating from 11-17°C (Sellers et al. 1985; NOAA 2014).

Total annual precipitation from 1976-2012 averaged 244 mm/year at Phantom Ranch, and with 50-100% greater precipitation on the South Rim (2073 m elevation) and 50-300% more on the North Rim (2590 m; Fig. 2.1), as compared to Phantom Ranch. Precipitation varies greatly among years, ranging from 76-380 mm annually at lowest elevations. About 40% of the annual precipitation falls during the summer “monsoon” rainy season between mid-July and early October. Precipitation is greatest about every five to ten years during strong “El Nino” Southern (Pacific) Oscillation events.

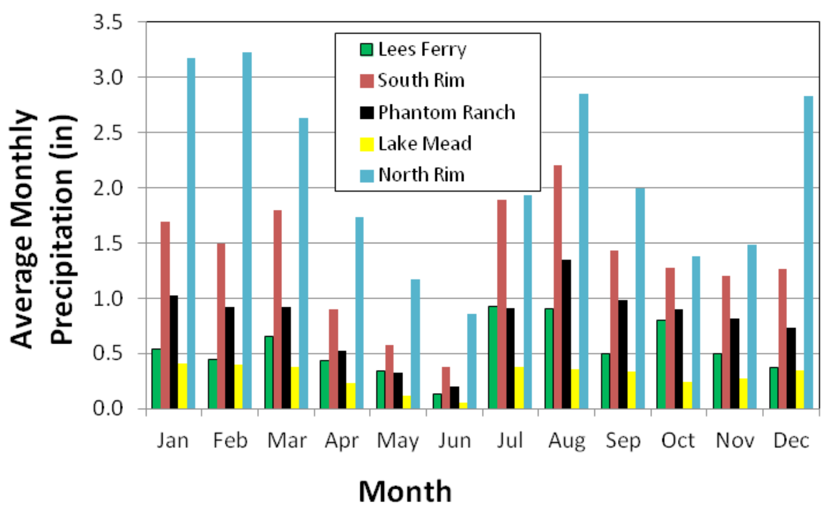


Fig. 2.1: Average monthly precipitation at Lees Ferry, South Rim, Phantom Ranch, Lake Mead, and the North Rim. All stations report a distinctive mid- to late-summer increase in precipitation during the summer monsoons.

Population Density and Socio-economics

There are few private in-holdings, and the GGCHNM region supports a remarkably small human population. The small towns of Tusayan, Grand Canyon, and Jacobs Lake each support only a small number of residents. We estimated the population within the proposed monument boundary by calculating the weighted sum of all the intersecting census block populations. For example, if a census block lay entirely inside the boundary, we added the entire census block population to the cumulative boundary population. If that census block lay only partially inside the boundary, then we multiplied the block population by the proportion of the census block that lay within the boundary. By this logic a census block with 100 individuals, which only lay 70% inside the monument boundary, would only contribute 70 individuals to the total boundary population. Our calculations are presented in Table 2.1 and Fig. 2.2.

Table 2.1 Human population estimates for the GGCHNM in 1990, 2000, and 2010, along with the number of intersecting census blocks and the total number of census blocks having no reported human population.

Census Year	Estimated Population	Total Number of Intersecting Blocks	Total Number of Intersecting Census Blocks with Population > 0	Proportion of Monument with Census Block Population = 0
1991	708	489	29	69%
2000	701	999	47	88%
2010	661	1178	51	93%

This population analysis indicates that approximately 661 individuals reside in the proposed GGCHNM, that 93% of the census blocks in the landscape have no human inhabitants, and that the population has been declining slightly in recent decades (Fig. 2.3).

The economics of GGCHNM are driven primarily by outdoor recreation, ranching, guided hunting outfitters, forestry (a salvage lumber mill operates in Fredonia, north of the proposed GGCHNM), federal or state governmental services, and visitor services. The Secretary of the Interior declared a moratorium on new uranium mining in 2012. The limited number of residents in the proposed Monument is overshadowed by the large number of seasonal employees in the lodging and dining services industry, and both are dwarfed by the enormous population of visiting tourists that come to the greater Grand Canyon region each year. Grand Canyon National Park alone attracted nearly 5.5 million visitors in 2015. Several thousand other visitors come to the area annually, either to sight-see, recreate, or hunt on the North Kaibab and, to a lesser extent to visit the Tusayan Ranger District. Thus, overall, the socioeconomics of the GGCHNM area are strongly driven by recreational tourism, and particularly by visitation to Grand Canyon National Park.

A Living Map of the GGCHNM Region

Below is a screen shot of a living map series of the landscape, biota, and forests of the GGCHNM region. These interactive maps are available to the public, and are hosted by ArcGIS Online.

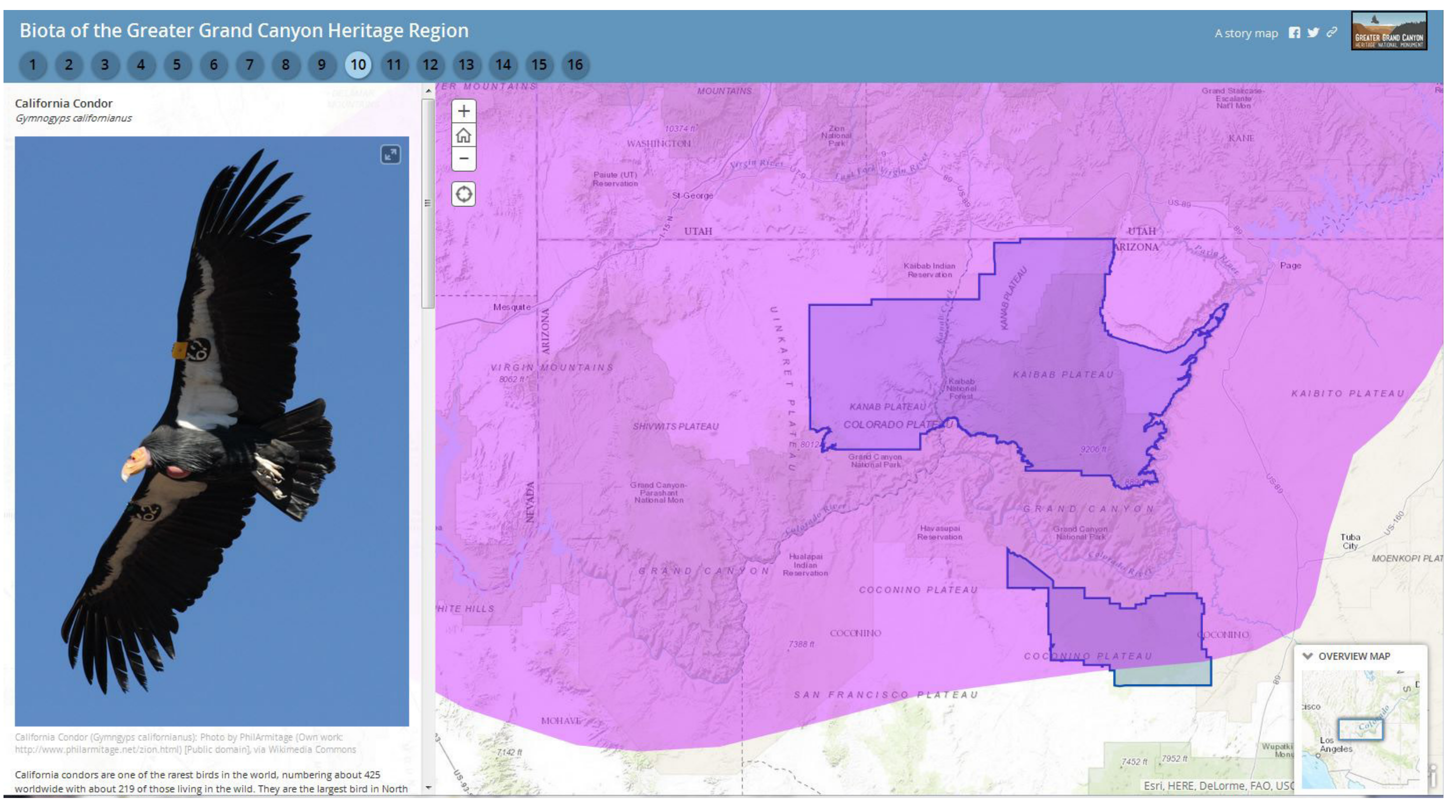


Fig. 2.2 Online interactive maps at http://arcg.is/1VWOXWX, http://arcg.is/1SOmiyj, and http://arcg.is/1qZdWMi.

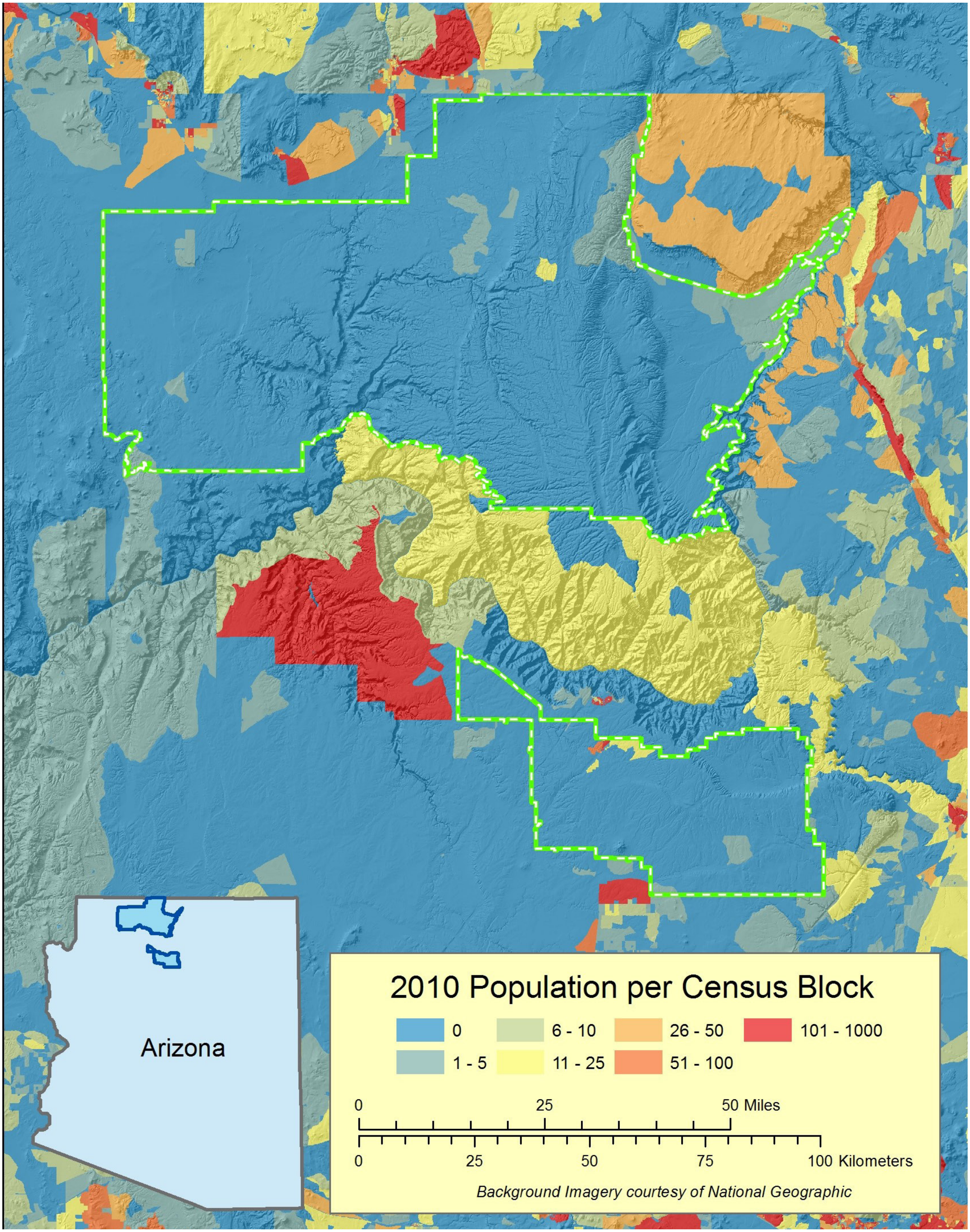


Fig. 2.3 Map of the population of GGCHNM in 2010 (census data coupled with GIS mapping by J. Jenness, SSI Flagstaff).

CHAPTER 3

GEOLOGY AND HYDROLOGY

KATIE JUNGHANS AND LARRY STEVENS

INTRODUCTION

The water feature most directly associated with Grand Canyon is the Colorado River, but this well known and highly visible water source derives 5 to 10% of its baseflow from groundwater aquifers lying beneath the proposed GGCHNM. The proposed monument's landscape supports more than 200 springs, where groundwater emerges from the Earth's surface. Springs are remarkably productive, species rich, and economically important ecosystems, but are anomalous among the thousands of hectares of waterless, rocky and dry-forested lands in this arid regions (Shepard 1993). The arid-land springs of the Grand Canyon region support rare desert ecosystems, supply drinking water to Arizona tourist and residents, and have enormous cultural value for the Native American Tribes in and around the region (Ross 2005). The nature of this region's largely karstic aquifers make the region's springs both productive and susceptible to degradation. Springs and their associated watersheds are at risk due to the substantial use of them by humans, the demand for further development in the region, and their susceptibility to degradation. In this chapter we describe the geohydrology of this vast landscape, and present information on how and why it supports such a wide and diverse array of springs.

GEOHYDROLOGY

The North Rim of Grand Canyon National Park is the southern edge of the Kaibab Plateau. The East Kaibab Monocline uplifted the Kaibab Plateau to elevations from 2400 m to 2800 m. The Kaibab Plateau receives an annual average precipitation of 669 mm/year, and is generally about 500 m higher in elevation than the South Rim. It receives approximately 250 mm (10 inches) more precipitation than does the South Rim. Winter storms provide about 60 percent of the Kaibab Plateau's precipitation. Extreme runoff events occur in early and late winter during rain-on-snow events, rapidly recharging the system though faults, sinkholes, and karst aquifers before emerging at springs located below the North Rim (Alpine 2010; Ross 2005). The major springs discharging from the Kaibab Plateau Redwall-Muav aquifer include Angel Spring, Emmett Spring, Roaring Spring, Abyss Spring, Tapeats Spring, Thunder Spring, Vasey's Paradise, Ribbon Falls Spring, and the Fence Fault Springs. Roaring Springs is Grand Canyon National Park's municipal water supply, providing water to over 5.5 million visitors in 2015, as well as to Park and concession employees (Brown 2011). Water derived from the GGCHNM supplies these pristine springs and streams with water, and the streams are among the only remaining pristine watersheds in the Southwest, if not the contiguous 48 states.

Several major structural trends control the regional hydrogeology of the Grand Canyon area. Faults, folds, fractures, and dip angles of bedding plans affect groundwater flow direction. South-sloping topography causes water to flow away from the South Rim, causing emergence of large springs below the North Rim and smaller springs below the South Rim. North-south trending faults exist in the western portion of the region; the Kaibab anticline, the Mesa Butte Fault, and the Havasu-Cataract Syncline dominate in the eastern portion.

The Kaibab Plateau is one of five plateaus comprising the North Rim of the Grand Canyon (Ross 2005). It occupies approximately 2460 (km^2) and is the most elevated portion of the Colorado plateau in northern Arizona (Huntoon 1974). The plateau dips gently westward and is structurally bound to the west by the scarps of the Muav Fault Complex, to the east by the East Kaibab Monocline, to the south by the sheer walls of the Grand Canyon and to the north by a regional dip of the Bright Angel Shale (Huntoon 1970, 1974).

On the Coconino Plateau south of the Colorado River, surface streams are ephemeral except for short ground or effluent water supplied perennial reaches. The Little Colorado River and Havasu Creek are the two largest tributaries which drain to the Colorado River. North Canyon and Kanab Creek are the only two substantial perennial streams on the Kaibab Plateau, but many springs emerge there, and natural perennial and ephemeral ponds abound. Surface streams are scarce because most water infiltrates into the aquifer or is lost though evapotranspiration, except during rare heavy rainfall events. The groundwater recharge potential is high on the Kaibab anticline (Alpine 2010).

Springs locations are strongly controlled by the secondary porosity created by dissolution along fault zones. The rock units which occupy the upper most portion of the Grand Canyon section are the most permeable and allow for vertical movement of groundwater. Almost all discharge occurs in springs over 900 m below the canyon rims where the downward movement of groundwater is prevented by units with relatively less permeability, like the Bright Angel Shale. Groundwater flows laterally atop of this layer with lower permeability and has caused extensive dissolution in the overlying Redwall and Muav Limestones. Groundwater flowing through these layers has caused enlarging of joints and fractures, resulting karst features such as caves, caverns, and solution channels. Groundwater preferentially flows within these features and many of the springs and seeps of the Grand Canyon are located at the contact of these permeable and impermeable layers.

Understanding the flow of groundwater in the study area requires comprehension of the geologic setting, and interaction of tectonic structures, and stratigraphy. Paleozoic aged rocks make up the upper 1200 m of exposed stratigraphy in the canyon. These rocks overlay Precambrian sedimentary rocks which rest upon a basement of metamorphic rocks. The Precambrian rocks have low permeability and are therefore not discussed here because they are not hydrologically significant. The hydrologic properties of the Paleozoic unit may be subdivided into four groups from bottom to top: (1) an impermeable clastic basal unit, (2) carbonates where conductivity is structurally controlled by zones of large permeability, (3) clastic rocks with low hydraulic conductivity, and (4) relatively permeable carbonate and clastic rocks (Huntoon 1974).

Layered zones of permeable and impermeable rocks make up two distinct aquifers: the Coconino-De Chelly Aquifer (C-aquifer) and the Redwall-Muav Aquifer (R-aquifer). The C-aquifer is perched above the R-aquifer and is composed of the Coconino Sandstone (Pc), Permian Toroweap Formation (Pt) and Permian Kaibab Formation (Pk). The R-aquifer is larger, deeper, and is composed of the Cambrian Muav Formation (Cm), Devonian Temple Butte Formation (Dtb), and the Mississippian Redwall Limestone (Mr). The impermeable Bright Angel Shale lies below the R-aquifer, serving as a basal aquitard and key to the R-aquifers existence.

Regional Structure and Stratigraphy

The GGCHNM region is a karstic plateau, with Paleozoic strata exposed near the Colorado River in Grand Canyon (Fig. 3.1; Billingsley 1978, Beus and Morales 1990). This Paleozoic sedimentary sequence of Grand Canyon formations extends through the GGCHNM and it is underlain by high grade metamorphic basement rocks, which are exposed on the floor of Grand Canon in crystalline inner gorges. These Paleozoic strata extend west to the Grand Wash Cliffs, where they underlie the Miocene to Pliocene aged lake beds, other volcanic flows and colluvium.

The northern GGCHNM lies between the Kanab Plateau on the west and House Rock Valley on the east. The region is structurally bounded by the Hurricane and Toroweap faults (Huntoon 1990): west-facing escarpments formed by these faults are curvilinear and essentially parallel. The areas where the escarpments bend are generally aligned to the northeast, suggesting a relationship to strike-slip faults in the adjacent Basin and Range province. Young, western fault zones along the western edge of the Colorado Plateau link Basin and Range extension to the GGCHNM region. With continued extension and fault movement, they will eventually form ranges and basins, adding to the extent of the Basin and Range province. The Basin and Range/Colorado Plateau transition is of considerable interest to modern geologists, and is revealed throughout the GGCHNM region in considerable complexity.

Hydrostratigraphic Units

The R-Aquifer

The strata that underly the GGCHNM region are superbly exposed in Grand Canyon. Here we focus on those that make up the R-aquifer, the largest and most important regional aquifer. The structure of the R-aquifer includes not only the Redwall Limestone and the overlying strata, but also the deeper confining Bright Angel Shale. All are described below. Fig. 3.1 depicts the general stratigraphic column of the strata described below. Schindel (2015) documented characteristics of the Kaibab Plateau and is synthesized below.

Bright Angel Shale

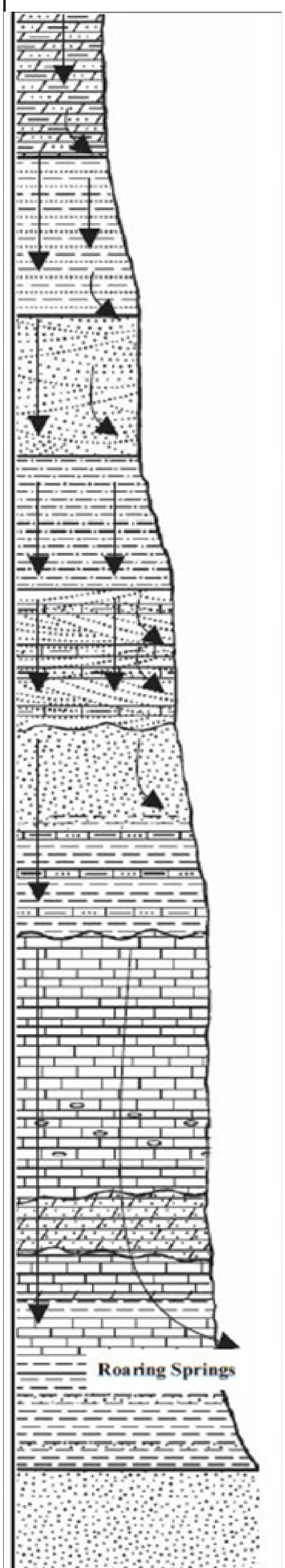
The Bright Angel Shale has a varying and irregular topography, lithology, and sedimentary structure due to its depositional subtidal marine environment where sedimentation varied with a changing high water line. On average, the thickness ranges from 100-120 m. On the eastern portion of the Kaibab Plateau, the Bright Angel Shale intertongues with the overlying Muav formation and ranges in thickness from a few centimeters to 5 m. The main lithological component is illitic clay, with smaller amounts of chlorite, kaolinite, and beds of fine-grained sandstone and siltstone. Striking purple and green color in the Bright Angel Shale are attributed to iron oxide cement, hematitic ooids, and glauconite forming cliffs or steep slopes. As a regional aquiclude, groundwater is forced to flow along top of the Bright Angel Shale and though the overlying R-aquifer. The topography of the R-aquifer is the main control on groundwater flow direction.

Muav Formation

Lying conformably above the Bright Angel Shale is the Muav Formation. Like the Bright Angel Shale, the Muav Formation was also deposited in a subtidal marine environment and due to changing water levels is inconsistent in thickness and lithology. Thinnest in the south and east of the study area, it has an average thickness of approximately 75-115 m. The laminated carbonate units contain intermittent thin beds of dolomite, calcareous mudstone, packstone, and flat pebble conglomerates in sporadic lenses and widespread in thin beds. Groundwater flows along top of the impermeable Bright Angel Shale, preferentially flowing though porous regions of fine-grained sandstone, conglomerates, and fractures. Unfractured rock units are largely impermeable. Groundwater dissolution enhances secondary porosity by creating karst conduits in the carbonate materials parallel and orthogonal to fractures (spaced roughly 0.6-2.4 m apart). Many springs discharge from gushet springs at the contact between the Muav and Bright Angel Shale. The largest springs in Grand Canyon National Park discharge at this contact.

Temple Butte Formation

The Temple Butte Formation was deposited in a westward draining tidal channel. It is present in lenses where channels were eroded into the top of the Mauv Formation. Thinnest in the north and east, it is usually less than 30 m thick though in places it exceeded widths of 120 m. The Temple Butte Formation is composed of limestone, sandstone, sandy dolostone, and dolotsone. Groundwater flows though fractures but, unlike in the Mauv Formation, there is little carbonate dissolution in the Temple Butte Formation and karst features are not present.



Section	Stratigraphic Name	Thickness (m)	Lithology	Hydrostratigraphy
	P Kaibab Formation	Variable due to erosion	The Harrisburg Member is gypsum dolostone, sandstone, redbeds, chert, and minor limestone. The Fossil Mountain Member is Cherty, fossiliferous limestone and siliciclastic dolomite.	C-AQUIFER Coconino Sandstone is primary water-bearing unit. Upper carbonates have well-developed secondary porosity. From Hart (2002): Transmissivity: 1.34 - 4,690 ft/d Hydraulic Conductivity 0.14 - 81.5 g/d/ft^2 Notes: Kaibab chert beds are impermeable; sandy Kaibab bed K = 2.7 x 10^{-3} g/d/ft^2 (Huntoon 1970). Toroweap massive gypsum K = 0.15 g/d/ft^2 (Huntoon 1970).
	P Toroweap Formation	80-160 m	Fine-to-medium-grained non-crossbedded sandstone inter-bedded with thin beds of evaporites, carbonates, and fine-grained, cross-bedded sandstone.	
	P Coconino Sandstone	90-120 m	Very fine to fine-grained, rounded cross-bedded eolian quartz sandstone with minor amounts of potassium feldspar.	
	P Hermit Formation	100-110 m	Reddish brown siltsone, sandy mudstone, and very fine-grained silty sandstone.	LEAKY AQUITARD Un-jointed rock samples of both Hermit Formation and massive fine-grained sandstone from the Supai Formation are impermeable: groundwater movement occurs along vertical joints and bedding oartings (Huntoon 1970).
	P Esplanade Sandstone	110-110 m	Cross-bedded fine-grained sandstone with thin beds of mudstone and limestone	
	P Wescogame, Manakacha, and Watahomigi Formations	160-170 m	The Wescogame Formation is primarily sandstone. The Manakacha is mixed quartz sandstone and red mudstone. The Watahomigi Formation consists of red mudstone, siltsone, gray limestone, and dolomite.	
	M Redwall Limestone	170-230 m	Overall a thick-bedded, cliff-forming, fine-grained limestone. Horseshoe Mesa Member: thin-bedded, fine-grained light gray limestone. Mooney Falls Member: chiefly pure limestone, with local dolomitization. Thunder Springs Member: alternating thin beds of limestone or dolomite and weathered chert. Whitmore Was Member: fine-grained limestone.	R-AQUIFER Supports base flow to springs >250,000 m^3/d (100 cfs). Muav is the primary aquifer on the Kaibab Plateau. Un-jointed samples of the Redwall, Temple Butte and Muav Fm. are impermeable; groudnwater moves through bedding plane partings, vertical joints or minor porosity of interbedded clastic constituents. Fault zones composed of breccia and fault gouge readily transmit water (Huntoon 1970).
	D Temple Butte Formation	20-70 m	Predominantly dolomite (often sandy) occurring as lenses.	
	C Muav Limestone	80-100 m	Horizontally laminated or structureless carbonate, dolomite and calcereous mudstone, and minor amounts of fine-grained sandstone or siltstone.	
	C Bright Angel Shale	70-80 m	Greenish shale and mudstone, containing thin beds of course-grained sandstone and conglomerate.	AQUITARD
	C Tapeats Sandstone	>100 m	Course-grained sandstone and basal conglomerate with significant quartz cementation.	AQUIFER Minor groundwater flow due to quartz cementation.

Figure 3.1: Generalized hydrostratigraphic column of the North Rim of the Grand Canyon P=Permian, M=Missipian, D=Devonian, C=Cambrian (Modified from Brown 2011).

Redwall Limestone

This unit is separated into four members: Whitmore Wash Member, Thunder Springs Member, Mooney Falls Member, and the Horseshoe Mesa Member. The Whitmore Wash Member is a fine-grained limestone with 0.6-1 m beds. The Thunder Springs Member is comprised of thin beds 2.5 -10 cm of alternating carbonate and chert and usually appears purple to pink in color. The Mooney Falls Member is predominately limestone beds from 0.6 to 6 m thick, forming much of the sheer Redwall cliffs in Grand Canyon. The Horseshoe Mesa Member is revealed in thin beds of limestone and is discontinuous due to partial erosion prior to deposition of later units.

Laying irregularly above the Muav and Temple Butte Formations is the Redwall Limestone. This unit thickens to the west and forms massive sheer cliffs ranging in thickness from 150 to 250 m in width. Groundwater flow following fractures and faults has resulted in significant karstification in the Redwall Limestone, especially in the lower Mooney Falls and Horseshoe Mesa members. Conduits which discharge large springs in the Redwall Limestone and Muav Formation are oriented in the same direction as fractures in the Redwall Limestone and Muav Formation.

Surprise Canyon Formation

When the Redwall Limestone existed at the surface, erosional features were cut into the Horseshoe Mesa member. The Surprise Canyon Formation filled in these features and presently exists in lenticular beds as carbonate layers in these paleovalleys. This formation is likely present within the Kaibab Plateau, but does not exist everywhere in the Grand Canyon (Beus 2003). The fractures of the Redwall Limestone relate to fractures in this formation (Roller 1987). Additionally, the Surprise Canyon Formation is of interest because breccia pipes are associated with it.

Supai Group

The Supai Group lies on top of the Redwall Limestone and is approximately 200-300 m thick, thickening to the east and west. Deposited in a coastal plain under transgression and regression conditions, the resulting lithology and local groundwater flow is varied and complex. This group contains a series of eolian and noneolian carbonate sandstones and red mudstones. The formations, in ascending order, are Watahomigi, Manakacha, Wescogame and Esplanade Formations.

The lower most formation is the Watachomigi Formation, a thinbedded, fine-grained unit composed of dolomite, siltstone, and mudstones. Above the Watachomigi are the Manakacha and Wescogame Formations. These are principally quartz and sandstone beds with thin beds of mudstone and dolomite. Finally, the Esplanade Formation lies atop of the Supai Group as a thick sandstone unit with eolian cross bedding, thickening to the north and west.

Groundwater flowing through these sections of mixed lithologies behaves in irregular ways. Groundwater moves vertically through sand dominated units until it reaches a mudstone or siltstone unit. These less permeable units cause groundwater to travel laterally and lead to discharge on the walls of the canyon. Well-developed joins and faults allow water originating from the top of the Kaibab Plateau to flow rapidly downward. The Supai Formation's mixed lithology, containing intermittent impermeable beds, results in many small perched aquifers which discharge as small springs within this unit.

Hermit Formation

The Hermit Formational is composed of sandstone and sandy mudstone and ranges in thickness from 25 m to 150 m. Beds within this formation are structureless and can be up to 1 m thick. Beds near the base of the unit are predominately sandy, gradually transitioning to mudstone towards the top of the unit. The Hermit Shale is impermeable where unfractured and small springs discharge from these regional aquitards.

Coconino Sandstone

The Coconino Sandstone was deposited in large eolian dunes of variable thickness, ranging from 75-150 m. The beds of this unit are composed of crossbedded fine to medium grained quartz sandstone and range in thickness from 1.5-23 m. The C-aquifer is composed of the Coconino Sandstone, Toroweap Formation and Kaibab Formation. Groundwater moved vertically though theses formation's fractures and laterally across the Hermit Shale aquitard. The C-aquifer lacks karst features and the springs which emerge from it are small compared to the springs of the R-aquifer.

Toroweap Formation

The Toroweap Formation was deposited in fluctuating marine environments, including shallow ocean, tidal flats, sabkhas, and eolian dune fields. This formation reaches a thickness of 150 m in Western Grand Canyon and pinches out entirely to the east (Ross 2005). This variable depositional environment resulted in dramatic changes and complex groundwater flow paths. The Seligman, Brady Canyon, and Woods Ranch Members make up the Toroweap Formation. The Seligman Member is the lower sandstone and evaporate unit. The Brandy Canyon Member is limestone, topped by the evaporate Woods Ranch Member. Some karst development is present in this formation.

Kaibab Formation

The top of the Kaibab Plateau is capped by the heavily karstified materials of the Kaibab Formation. Deposited in a marine environment with fluctuating sea level, this carbonate-siliciclast ramp thins towards the east of the Grand Canyon. Lying atop of the evaporitic gypsum of the Toroweap formation, the Kaibab Formation contains siliciclastic sediments and carbonates mixed with diagenetic dolomites and chert. The two members of the formation are the Fossil Mountain member, which is 75% sandstone or sandy dolostone, and the Harrisburg Member, a mix of gypsum, dolostone, sandstone, redbeds, chert, and minor limestone.

Unfractured chert-containing limestones have no permeability in the Kaibab Plateau. Heavy karstification has created over 2000 identified sink holes on the surface of the formation. This secondary porosity allows for rapid

Figure 3.2: View of stratigraphic layers visible from Gunsight Point. Kanab Creek flows through this portion of the Canyon. Image by Kristen M. Caldon.

infiltration of precipitation into the subsurface and is responsible for the development of uranium-containing breccia pipes. Where the Toroweap and Kaibab Formations are in contact, regions of local impermeability results in discharge of many small springs.

Karstic Setting

Karst is terrain with distinctive hydrology and landforms, and develops in readily soluble materials, such as limestone, marble, and gypsum. Secondary porosity is enhanced by dissolution due to the preferential flow of water along fractures and joints in these rocks. Karst terrains are characterized by extensive underground aquifers, caves, sinkholes, and large springs. Karst carbonate aquifers are highly productive, supplying roughly one-third of the United States with drinking water (Schindel et al. 1996). Karst aquifers with the most extensive secondary porosity are made of dense, massive, pure, and coarsely fractured rocks. Since meteoric waters are the most common cause of dissolution, the majority of karst aquifers are found within tens of meters to the surface elevation (Ford and Williams 2007).

The four modern groundwater basins of the central-eastern part of the Grand Canyon identified by Huntoon (1974, 2000) are the Cataract, Black Mesa, Kaiparowits, and Kaibab Plateau. Figure 3.3 depicts the areas of interest, contained in the Kaibab Plateau, Cataract Basin, and Black Mesa. Kaibab Plateau water discharges from unconfined systems, while Cataract and Black Mesa waters discharge from confined aquifers.

The Cataract groundwater basin drains much of the Coconino Plateau, discharging from the R-aquifer at Havasu Springs. Black Mesa basin is approximately 70,000 km^2, discharging at the Blue Springs complex. These confined aquifers are hypogenic in origin, having formed though a condition called "mixing corrosion" (Ford and Williams 2007). Hypogenic dissolution in the Grand Canyon region occurred below the water table where meteoric waters and deep, upwelling waters mix. Groundwater tends to flow relatively slowly though these isolated pockets of porosity which, unlike vadose karst, lack integrated conduit systems. As a result, springs in these basins tend to have small and consistent discharge.

Due to the Kaibab Plateau's elevation, it receives significantly more precipitation than the other basins. Most of this precipitation drains to five major vadose springs where the plateau is dissected by the canyon. This unconfined aquifer is rapidly recharged though a number of sinkholes, then usually descends to the base of the Muav where it discharges from unconfined caves (Hill 2010). The generally unconfined nature of Kaibab Plateau aquifers are subject to seasonal variation in groundwater supply. Snow melt and heavy precipitation during spring cause groundwater mounds to develop above confining layers and provide increased discharge to springs. Groundwater mounds dissipate during the dry summer and fall season, resulting in significantly diminished or ceased spring and seep discharges (Huntoon 1980).

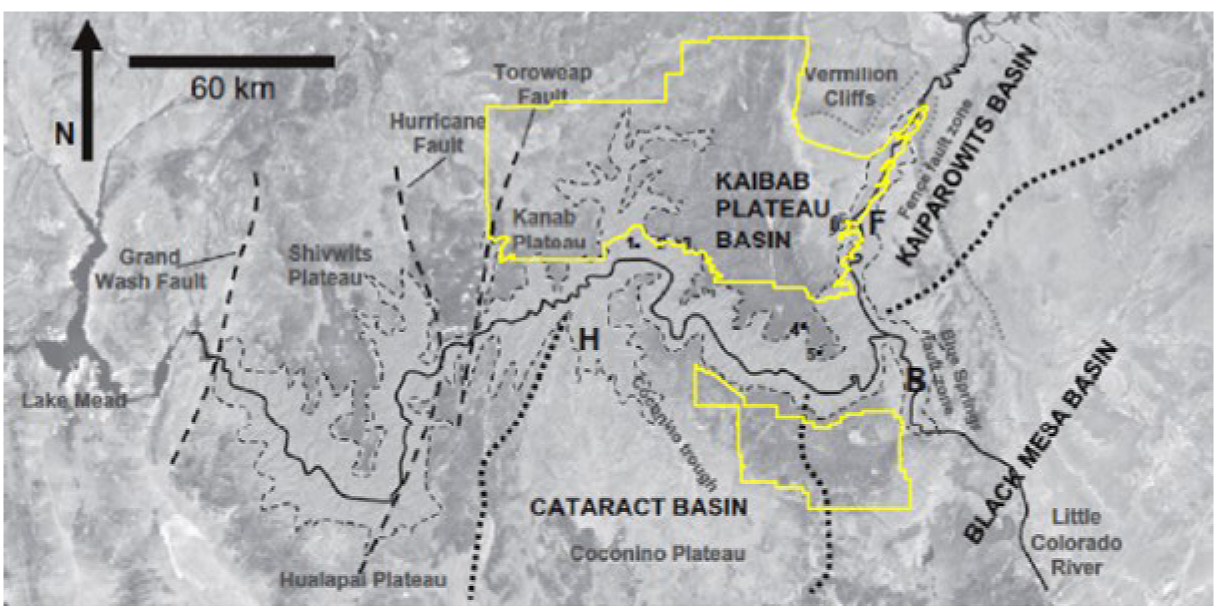


Figure 3.3: Regional geologic structure of the GGCHNM region (after Hill and Polyak 2010).

These water bearing units have been uplifted above the regional groundwater base level as the Colorado River cut down to form the Grand Canyon. The surrounding area is well drained due to the plateau's high elevation and topographic isolation caused by the deep canyon cutting. Therefore, most of the regions discharged water leave the plateau through down dip springs and seeps along the walls of the Grand Canyon (Huntoon 1980). The sedimentary beds in the Grand Canyon dip slightly to the south causing a majority of the R-aquifer's regional groundwater to discharge on the North Rim at the base of the confining Muav Formation though large conduit-driven springs (Huntoon 1995).

The conduits in the R-aquifer can rapidly transport large volumes of water with minimal duration of groundwater storage (Huntoon 2000). During severe rain events, flood waters travel several kilometers between the surface of the plateau and the springs in a matter of days. Comparatively, waters in Cataract Basin and Black Mesa Basin take hundreds to thousands of years to travel similar distances (Huntoon 1980).

The Kaibab Plateau sustains high groundwater recharge rates for several reasons. Standing more than 800 m higher than its surroundings, its physical setting creates an orographic barrier. The associated cooler temperatures and higher precipitation allow for lower evaporation rates compared to its desert surroundings. The Kaibab Plateau has no surface streams despite the lowest ratio between potential evaporation and actual precipitation of any portion of the Grand Canyon (Figs. 3.4, Fig. 3.5). This is possible due to the highly porous units which compose the upper portion of the plateau and allow great opportunity for groundwater's vertical migration and recharge of aquifer systems (Huntoon 1980).

Except for Havasu Springs, springs on the South Rim are generally smaller because recharge rates over the area are lower and groundwater flows southward. Grand Canyon National Park relies solely on the North Rim's Roaring Springs its water source. Despite the importance of this water source, the understanding of groundwater's behavior in the R-aquifer is deficient because of its depth, complexity of flow, lack of wells, and remoteness of discharge points (Schindel 2015).

VULNERABILITY OF KARST AQUIFERS

Karst environments are particularly vulnerable to human impacts compared to other natural settings due to the nature of their hydrologic properties. Karst hydrologic systems are capable of transporting surface water efficiently downward into a numerous, widely spread conduits with geometries that are rarely understood. Water enters the system essentially unfiltered because limestone soils are generally thin, conduits have large dimensions, and rapid transmission of water may limit filtering and die-off of pathogenic organisms.

Although surficial containments and potentially radioactive ore bodies exist 150-350 m above the regional R-aquifer, these contaminates can reach perched groundwater at detrimentally high concentrations (Alpine 2010). Management of these complex and concealed systems requires specialist knowledge and once damaged can be extremely difficult to restore. European Union countries have recently made considerable effort to protect the quality and quantity of karst systems on the European continent (Ford and Williams 2007).

MINERAL RESOURCES

Potentially valuable minerals are rare on the southern Colorado Plateau, occurring in two types of settings (Billingsley et al. 1997): 1) Breccia pipes that form through collapse of limestone solution chambers and contain uranium, and sometimes copper and small amounts of silver, and gold; and 2) Small copper deposits that occur in chert brecchias within the Harrisburg Member of the Permian Kaibab Limestone. That limited amounts of copper were extracted historically from the region indicates that copper is of little economic importance in the region (G. Haxel, written communication). Other minerals of minor economic interest include gypsum, sand and gravel, flagstone, cinders, gas or oil, asbestos, and ornate minerals. However, the remoteness of the region and the condition of existing roads is an obstacle to profitable extraction. While most mineral resources in the region are of minor economic importance, the same cannot be said about uranium.

Uranium is found in the more than 1,300 solution-collapse breccia pipes on both rims of Grand Canyon (Finch no date). These 30-175 m-wide vertical pipes are filled with ceiling spall and broken rock. Breccia pipes initially

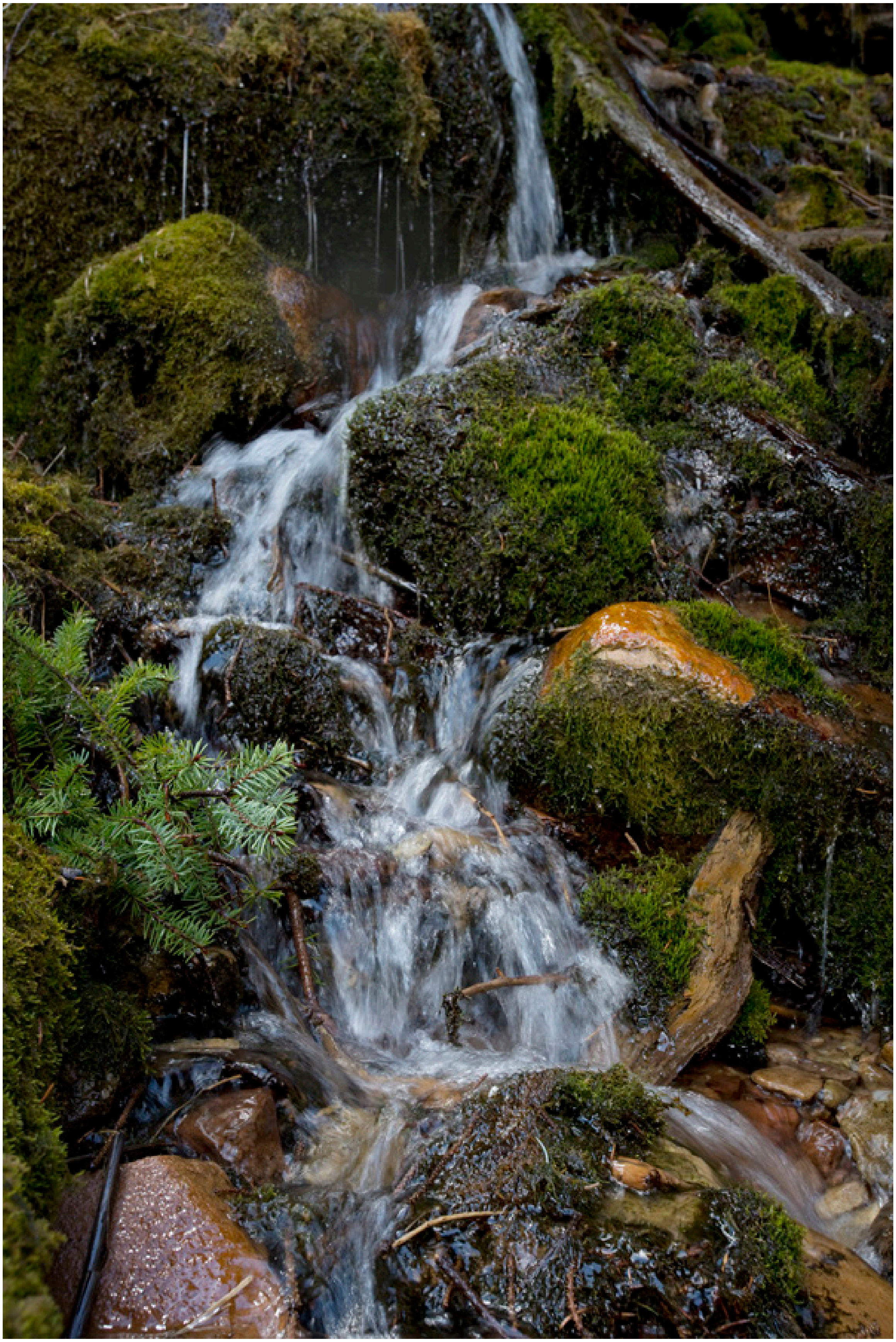


Figure 3.4 North Canyon Spring on the North Rim of the Grand Canyon. The spring emerges from the Coconino Formation. Photo by Kristen M. Caldon.

formed as solution caverns collapsed in Mississippian-age Redwall Limestone. The ceiling collapses propagated the pipes upward 1,000 m or more through overlying Paleozoic and Mesozoic strata, up to the late Triassic lower Chinle Formation. Collapse of the cavern ceiling continues upward into overlaying formations over time, forming rubble-filled columns. The porous breccia pipe materials may become cemented with a variety of minerals, brought in by geothermal water. The uranium ore in GGCHNM brecchia pipes is Mesozoic in age, approximately 200-260 million years old, and was deposited at geothermal temperatures of 80-173°C (Wenrich 1985, Ludwig and Simmons 1988, Wenrich and Sulphin 1988).

Figure 3.5 A Coconino Sandstone wall overhanging Castle Spring in Kaibab National Forest. Water seeps from beneath the stone wall and channelizes into the terrace below. The site could have supported prehistoric peoples due to its solar radiation budget. In more recent years, the walls have been heavily graffitied, leading to a restoration of the site between 2013 and 2015. Image by Molly Joyce.

Some of the highest grade uranium ore in the United States is located in the many mineralized breccia pipes scattered across the Grand Canyon region. Mining of these breccia pipes began in the 1950s and continued intermittently though the early 1990s, mostly in the Kanab Creek drainage found within the proposed GGCHNM boundary. Nearly 8,500 claims for uranium have been filed, and 1,500 exploratory wells have been drilled. At present there are four mining companies active in the region and the three active uranium mines (Arizona 1, Canyon Mine, and Pinenut Mine) (https://miningawareness.wordpress.com/2015/06/07/concerns-with-uranium-mining-in-the-grand-canyon-region-usgs/).

Due to the great depth of the uranium deposits, breccia pipe mines in northern Arizona since the 1980s have been underground operations. Employing subsurface tunnels and access shafts, rock is crushed to fist-sized pieces, brought to the surface in vertical shaft mines, and transported to milling operations for mineral extraction and recovery. Large quantities of waste materials are generated though uranium mining because the ratio of usable uranium to mined rock is low, ranging from tenths of a percent to single digit percentages. Waste materials associated with conventional mining are characterized by low-level radiation, heavy metals, and other inorganic and organic materials.

Uranium mining in northern Arizona left waste rock and low-grade ore exposed at the surface before stricter environmental regulations in the mid-1970s. Remobilization of minerals and radionuclides in these materials allowed for contamination of surface water and groundwater (Fig. 3.6). The great number and extent of breccia piping increases the potential for contamination in karst hydrologic systems, along with the accelerated erosion of mineral deposits associated with mining development, and the presence of uranium and arsenic associated with mined sites caused concern about environmental degradation. Features such as fractures, faults, sinkholes, and breccia pipes provide pathways for downward migration of surface waters and groundwater. This process that dissolves trace elements and radionuclides in mineralized zones, transporting them deeper in the subsurface and into groundwater supplies.

In 2009, the U.S. Geologic Survey conducted an assessment of historical and current water-chemistry data for wells, springs, and streams in the Grand Canyon region. In that study, low levels of uranium were detected in almost all natural water samples (95 percent) and historical water-quality data showed that dissolved uranium in areas with and without mining were generally similar - representing the abundance of natural dissolution and erosion of ore deposits in the area. Samples from 15 springs and 5 wells contained uranium concentrations exceeding the Environmental Protection Agencies maximum drinking water standard and were found to be related to natural processes, mining, or a combination of both factors. The groundwater-chemistry relations between concentrations and mining conditions were found to be limited and inconclusive.

Contamination at the surface showed a stronger correlation to mining practices and varied according to physiographic setting, length of time waste materials were exposed at the surface, and effectiveness of reclamation at the site. Wind dispersion of dust caused contamination of soils beyond the mining sites. Surface water spread contaminates across mining sites and beyond into channels and floodplains of stream channels. Experimental simulations of leaching from waste-rock samples found very high uranium concentrations (several hundred to several thousand parts per billion) in some cases.

Contaminates found in natural settings are subject to very large dilution as they mix with their surroundings. The inconclusive groundwater-chemistry results may be a consequence of the travel distance and duration water experiences in this region. Groundwater travels downward approximately 900 m in the Grand Canyon before being discharged, allowing for adequate time for dissolution to occur. Wind and surficial water driven contaminates have a more limited range of dispersion and were thus found more closely associated with mining operations. Though naturally occurring uranium is found throughout the Grand Canyon, the study by the USGS provides evidence that mining practices enhance the susceptibility of increasing environmental uranium contamination.

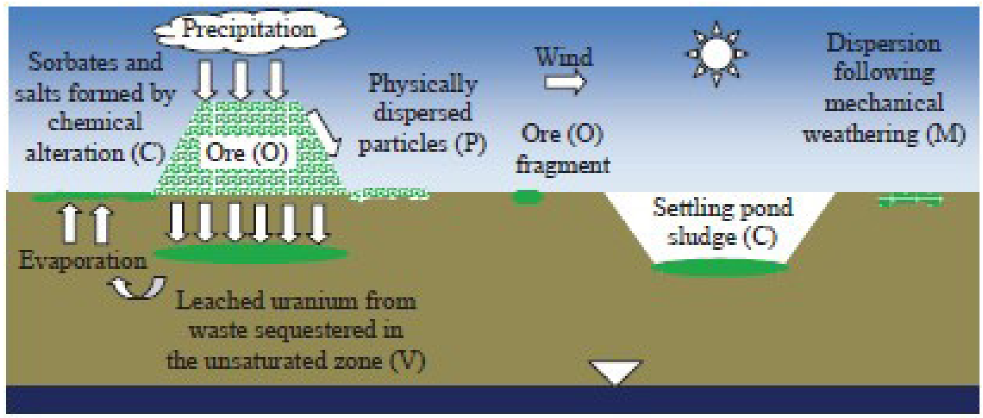


Figure 3.6 Modes of dispersal of stored ore and mined waste at mine sites (Alpine 2010).

Threats created public concern included the effects of industrial operations on air, groundwater, and natural resources in the Grand Canyon region, especially from increased truck traffic and other operations. In 2012 Secretary of the Interior Ken Salazar announced a 20-year withdrawal of 1.07 million acres of federal land from uranium mining (Daly 2012), a decision that was supported by a Federal District Court in 2014. However, neither the announcement nor the subsequent legal contest reduce the number of claims or prevent existing mining operations from continuing. For example, the Canadian mining company Energy Fuels Resources has been approved to reopen its uranium mining operations at Old Canyon Mine, just 10 km south of the South Rim of Grand Canyon.

RECENT PALEOARCHEOLOGY AND CLIMATE CHANGE

Sediment cores and pollen records over the past 13,500 years were obtained from Fracas Lake (2,518 m elevation) and Bear Lake (2,778 m elevation; Weng and Jackson 1999). They reported that before about 13,000 years ago, the lower elevations of the Plateau were covered by spruce woodland, while upper elevations were covered by tundra. At the conclusion of the Pleistocene epoch 12,900 years ago, Engelmann spruce and subalpine fir forests expanded, but that ponderosa pine did not begin to expand into the lower elevations until 11,000 years ago and did not reach the upper elevations until after 9,500 years ago. Spruce, subalpine fir, and ponderosa pine remain in the area, although Engelmann spruce reinvaded the upper elevations after 4,000 yr ago (Fig. 3.7). Based on charcoal in the pond sediments, Weng and Jackson (1999) concluded that forest fires probably facilitated ponderosa pine establishment at higher elevations on the Plateau.

Altschul and Fairley (1989) reviewed the literature on Pleistocene/Holocene paleoenvironmental change on the southern Colorado Plateau, including the Arizona Strip. The arrival of prehistoric humans and Pleistocene/Holocene climate changes are considered the causes of the extinction of Pleistocene megafauna in this region, including elephants, camelids, Harrington's mountain goat, Shasta ground sloth, numerous large predators, and giant *Tera-*

tornis (quasi-raptorial birds). Analyses of packrat middens, plant distribution and general atmospheric circulation models indicated that the jet stream was displaced to the south during the Wisconsin Glacial phase (prior to 12,000 years before present, ybp; Mitchell 1976, Betancourt 1984). Increased frequency of winter storms has likely increased winter precipitation, decreased summer precipitation, and resulted in warmer summer temperatures.

Rapid vegetation change occurred from 12,000 to 8,000 years ago, as boreal spruce, limber pine and dwarf juniper disappeared from lower elevations and species ranges retracted to the upper elevations of the North Kaibab and the San Francisco Peaks. Data from several sites on the southern Colorado Plateau indicate that ponderosa pine, gamble oak, one-seed juniper and, later, pinyon pine, arrived in the region between 10,000 and 7,200 years ago. The present summer monsoon boundary formed during this period, although the present vegetation composition was not fully in place until 2,000 to 3,000 years ago. Geomorphic, palynological and dendrochronological data suggest that droughts were relatively common, with 10-30 yr dry periods from the early AD 200s to the early 900s, increased precipitation from the early 900s to AD 1210, a return to erratic droughts to AD 1500, generally moist conditions from AD 1500 to the mid 1800s, and a return to erratic droughts through the 20th century. Generally, periods of higher moisture availability are associated with pulses of human agricultural activity. While the information assembled is generally applicable to the Kaibab Plateau, much remains to be learned of the region in relation to this general model.

Figure 3.7 A view of Sieber Point from Saddle Mountain. Photo by Kristen M. Caldon.

CHAPTER 4

BIOLOGY AND ECOLOGY

LARRY STEVENS

Biomes and Ecosystems

The life zones described by C. Hart Merriam (1893, 1894) in and around the San Francisco Peaks and Grand Canyon regions present a snapshot-in-time of vegetation responses to a highly dynamic and changing climate. In the GGCHNM region, these life zones include, from low to high elevation: the Lower Sonoran desert-scrub; the Great Basin conifer woodland pinyon pine, juniper, and big sagebrush Upper Sonoran Zone; the ponderosa pine-dominated Transition Zone; the montane mixed conifer and aspen Canadian Zone; and the subalpine conifer forest Hudsonian Zone. The GGCHNM does not reach sufficiently low elevations for Sonoran-Mohavean desert shrublands, nor high enough elevations for arctic alpine habitat. Nonetheless, the region supports a tremendous range and variety of vegetation types, which form the ecosystems found in the landscape (Brown 1994). Extensive research on Pleistocene and Recent paleontology in the region has revealed dramatic and rapid responses of vegetation to changing climate, particularly since the end of the Pleistocene epoch (e.g., Martin and Klein 1984; Phillips et al. 1987).

Vegetation

Overview

The vegetation of the GGCHNM region has been the subject of scientific investigations since prior to the turn of the 20th Century (Merriam 1894), and its ecotones and vegetation processes have been the subject of additional botanical studies (e.g., Rasmussen 1941, Harper and Reveal 1977, Meyer 1978, Brown 1994, McLaughlin and Bowers 1998, Moore et al. 1999). This region lies at the interface between the Mojave, Sonoran, Great Basin Desert biomes with the Plateau Rocky Mountain biome. Brown (1994) and more recently McLaughlin and Bowers (1998) described the floristic provinces of the Southwest, identifying the GGCHNM region as supporting elements of all of the above vegetation assemblages (Fig. 4.1). The interactions among these biomes and floristic provinces over time has resulted in the co-occurrence of at least 1,500 plant taxa, with additional species likely to be detected with more detailed inventories. The region is dominated by a few, rather widely distributed vegetation types, including grasslands, pinyon-juniper woodlands, ponderosa pine forest, aspen, and mixed conifer forests. Although low elevations are sparsely vegetated, canyon slopes and few springs support lush riparian vegetation, and forests and large meadows dominate the upper elevations. Some of the GGCHNM plant assemblages are rare, unusual or unique and reflect long-term changes in climate and the region's unique position and biogeographic history.

Desert Vegetation

The Warm-Temperate Mohave Desertscrub assemblage occurs in lower elevations in Kanab Creek. That drainage supports Mormon tea (*Ephedra* spp.), many desert grass species, saltbush (*Atriplex* spp.), and various cacti and other shrubs. Semi-desert Warm-Temperate Grassland vegetation occurs in patches, particularly on north-facing slopes, and that in the Kanab Creek drainage. This vegetation type was previously subject to intensive livestock grazing.

Pinyon-Juniper Habitat

The middle elevations of GGCHNM are dominated by junipers and pinyon pines (*Pinus monophylla* and *P. edulis*), which exist in vast woodlands up to elevations of approximately 2,000 m and make up much of the land coverage (Merkle 1952, Holland et al. 1979, Callison and Brotherson 1985, Phillips et al. 1987). The Kanab and northern Coconino Plateaus are dominated by a one-seed and Utah juniper (*Juniperus utahensis* and *J. osteosperma*), as well as pinyon pines (*Pinus spp*.), barbery (*Berberis spp*.). The understory beneath pinyon-juniper stands is typically sparse, with sagebrush (*Artemesia spp*.) and scrub oak (*Quercus turbinella*), which is more drought tolerant than its higher elevation counterpart, Gambel's oak (*Quercus gambelii*; Neilson and Wullstein 1985). Snakeweed (*Gutierrezia sarothrae*), banana yucca (*Yucca baccata*) and various cacti also are common (Dutton 1882, Hoffmeister and Durham 1971). These vegetation assemblages are part of the Cold-Temperate Grasslands, Desertlands, and Scrublands described in Brown (1994).

Gambel's Oak Shrublands and Chaparral Habitat

South-facing slopes on the plateaus and on canyon sides are covered in mixed shrub-, woodland, and chaparal flora, particularly including New Mexican honey locust (*Robinia neomexicana*), manzanita (*Arctostaphylos pungens*), mountain mahogany (*Cercocarpus montanus*), and Gamble's oak (*Quercus gambelii*). The latter species forms large stands on sloping colluvial surfaces and strongly dominates upper elevation hillsides. High desert chaparral covers a small percentage of the GGCHNM escarpment edges, and also is part of the Cold-Temperate Scrublands habitat described in Brown (1994).

Sagebrush Habitat

Large stands of bigtooth sagebrush (*Artemesia tridentata*) occur in natural and chained open areas on the GGCHNM region. Snakeweed is abundant, particularly on grazing-disturbed uplands, and rabbitbrush (*Chrysothamnus nauseosus*) is also common. Great Basin Sagebrush Desertscrub and Plains Grassland make up a minor percentage of the regional vegetation cover (Holland et al. 1979). Sagebrush Meadow habitat dominated by big sagebrush (*Artemesia tridentata*) and other shrubs Snakeweed (*Gutierrezia sarothrae*), banana yucca (*Yucca baccata*) and various cacti also are common (Dutton 1882, Hoffmeister and Durham 1971). This vegetation is part of the Cold-Temperate Grasslands, Desertlands, and Scrublands described in Brown (1994).

Ponderosa Pine Habitat

Ponderosa pine (*Pinus ponderosa*) is a widespread western pine that occurs broadly across the GGCHNM at higher elevations, covering a large portion of the uplands. The upper elevation vegetation of the proposed monument is similar to that in the Rocky Mountains (Rasmussen 1941, Merkle 1962). In addition to its occurrence across the North Kaibab, ponderosa pine often occurs as riparian "stringers" in the small drainages that flow off the plateau: water courses in the upper elevation pinyon pine/juniper habitats are marked by long narrow stands of ponderosa pines. The understory beneath ponderosa pine here includes a typically sparse grass, herb, and mixed shrub assemblage, with Gambel's oak, sagebrush, mountain mahogany, and various grasses. Ponderosa pine has been in the region for approximately 10,400 years (Moore et al. 1999).

Mixed Conifer Vegetation

The highest elevations of the GGCHNM exceed 2,700 m, and are dominated by mixed conifer forest, with many open prairie-like meadows. Common high elevation trees include aspen (*Populus tremuloides*), Englemann spruce (*Picea engelmannii*), and white fir (*Abies concolor*).

Riparian Vegetation

Riparian habitats make up <0.5% of the landscape area in the Grand Canyon region, but support >35% of the plant species that exist there (Stevens and Ayers 2002). Springs make up <0.01% of the overall landscape, but support >10% of the region's plant species. Therefore, riparian areas, particularly those related to springs are disproportionately rich in species.

The general absence of water precludes development of much deciduous or riparian woody vegetation in this region; however, desert Warm-Temperate Riparian Wetlands occur along low elevation creeks and at springs. Those habitats are dominated by sparse Fremont cottonwood (*Populus fremontii*), Goodding's and coyote willow (*Salix gooddingii* and *S. exigua*), but gallery stands of cottonwood or willow do not presently exist on the proposed Monument. Rather, these Mojave Strandline habitats are more strongly dominated by various graminoids and herbs, and with peripheral rubber rabbitbrush (*Ericameria nauseosus*), lemonade-berry (*Rhus trilobata*), catclaw (*Acacia greggii*), and other desert grass and shrub species (Brown 1994). Higher elevations support wet meadows, a few perennial streams, and many springs, with aquatic and phreatophytic growth.

Springs vegetation stands out strongly against the non-riparian upland habitats. For example, Big Springs at the Big Springs Ranger Station on the west side of the Kaibab Plateau is a large, cold-water gushet that pours out of the base of the Coconino Sandstone. It supports a lush stand of Gambel's oak, stinging nettle (*Urtica dioica*), and abundant moss, wetland and aquatic plant life. Other GGCHNM regional springs, such as North Canyon Springs, support high concentrations of endemic species of insects and plants. Due to their profuse vegetation and the occurrence of rare species, springs are recognized by the Kaibab National Forest as habitats worthy of special consideration (U.S. Forest Service 2014). However, many springs in GGCHNM have been developed and their water diverted for livestock or human consumption.

Ledbetter et al. (in press) indicate that nearly 200 springs have been documented on the area of the proposed Monument. These Forest springs are known from historical accounts and were hydrologically inventoried during a synoptic study by the Grand Canyon Wildlands Council (2002) and the Springs Stewardship Institute (http://springsdata.org). These studies document information on discharge, vegetation, and human use of springs, >75% of which have been largely or completely developed for human use and livestock watering. However, there are many unmapped springs in the region, particularly those emerging from the base of the Coconino Sandstone in the Kanab Creek drainage. Some of those springs are virtually pristine, and support naturally high densities of wetland plants and invertebrates. These springs have direct hydrologic connections to the aquifers of the North Kaibab. In contrast, there is only a one known dry springs ecosystem on the southern portion of the GGCHNM.

The biota of GGCHNM springs has been initially described (Clover and Jotter 1944, Grand Canyon Wildlands Council 2002, Ledbetter et. al. in press). Upper elevation GGCHNM springs support several rare, endemic invertebrates, including several elmid beetles, a unique *Nebria* ground beetle, and a unique stonefly species (presently being described by Dr. Richard Baumann, BYU Monte L. Bean Museum), as well as a remarkable array of wetland wildflowers, including a rare, giant-flowered columbine (near *Aquilegia cerulea*). Lower elevation springs supports cardinal flower (*Lobelia cardinalis*), maidenhair fern (*Adiantum capillus-veneris*), redbud trees (*Cercis occidentalis*), and a host of other wetland species.

Management concerns exist over grazing and the invasion of non-native plant species at springs because these habitats host great biological diversity and are fragile and particularly susceptible to invasion (Stevens and Ayers 2002). Castle Spring on North Kaibab Ranger District was used for more than a century for livestock water. It was recently rehabilitated by a joint US Forest Service, Native American, and NGO team to restore its ecological integrity. Although the geomorphic reconstruction of the site was highly successful, management of the site continues to be challenged by a legacy of non-native weed species invasions. Successful removal of non-native plant species from springs has been accomplished at some springs in the region (Burke et al. 2015), but such efforts are time- and labor-intensive. Both the U.S. Forest Service and the Bureau of Land Management have fenced off springs to reduce livestock grazing, but more stewardship is needed to reduce landscape and resource damage due to introduced hybrid Bison grazing impacts on springs, spring-fed ponds, and fens.

Rare Plants

As Charles Darwin noted, most species are rare, so it is not surprising that a rather large number of plant species in the proposed GGCHNM are rare. However, some of those species are endemic to the region, and warrant special mention (Table 4.1). Prominent among those are the Kaibab Bigelow's Tanseyaster (Asteraceae: *Dieteria bigelovii* var. mucronata), Kaibab bladderpod (Brassicaceae: *Physaria kaibabensis*), listed Fickeisen Plains Cactus (Cactaceae: *Pediocactus peeblesianus* var. *fickeiseniae*), Kaibab Pediocactus (Cactaceae: *Pediocactus paradinei*), Kaibab Mexican Skullcap (Lamiaceae *Scutellaria potosina* var. *kaibabensis*), Kaibab Indian Paintbrush (Orobanchaceae: *Castilleja kaibabensis*), and Kaibab Wright's Birdbeak (Orobanchaceae: *Cordylanthus wrightii* subsp. *kaibabensis*). Of these, only the Fickeisen Plains cactus is federally endangered (http://www.fws.gov/southwest/es/arizona/Documents/Redbook/Fickeisen_Plains_Cactus_RB.pdf).

Table 4.1: Rare, restricted, or endemic plants of the proposed GGCHNM (list compiled by Glenn Rink, Northern Arizona University Department of Biological Sciences, Flagstaff).

Plant Family and Species Name	Distribution Notes
Apiaceae Pteryxia petraea	endemic to GRCA region
Asteraceae Chrysothamnus molestus	endemic to N AZ
Asteraceae Dieteria bigelovii var. mucronata	endemic to the KP
Asteraceae Ericameria arizonica	endemic to rims of GC
Asteraceae Erigeron lobatus	nearly endemic to AZ
Asteraceae Hesperodoria salicina	GC endemic
Asteraceae Hesperodoria scopulorum	endemic to S CP
Asteraceae Hymenoxys subintegra	probably a KP endemic
Asteraceae Packera quercetorum	AZ endemic
Asteraceae Perityle ciliata	early Jones collection
Boraginaceae Cryptantha atwoodii	endemic to the GC area
Boraginaceae Cryptantha semiglabra	endemic to AZ/UT border
Boraginaceae Ellisia sp.	Goodding specimen at ASC
Boraginaceae Phacelia cephalotes	nearly endemic to Strip and SW Utah
Boraginaceae Phacelia constancei	endemic to southern CP
Boraginaceae Phacelia furnissii	endemic to the AZ Strip
Boraginaceae Phacelia hughesii	endemic to the AZ Strip
Boraginaceae Phacelia pulchella var. atwoodii	endemic to AZ Strip and SW Utah
Boraginaceae Phacelia pulchella var. pulchella	endemic to AZ Strip and SW Utah
Brassicaceae Physaria kaibabensis	KP endemic
Cactaceae Coryphantha missouriensis	probably endemic to N AZ
Cactaceae Pediocactus bradyi	endemic to Marble Canyon area
Cactaceae Pediocactus paradinei	endemic to east Kaibab momocline?
Cactaceae Pediocactus peeblesianus var. fickeiseniae	endemic to N AZ
Cactaceae Sclerocactus sileri	endemic to HR Valley/Vermillion Cliffs
Cyperaceae Carex curatorum	endemic to the CP
Cyperaceae Fimbristylis	Goodding specimen at ASC
Euphorbiaceae Euphorbia aaron-rossii	Grand Canyon/Glen Canyon endemic
Fabaceae Astragalus atwoodii	endemic to AZ Strip
Fabaceae Astragalus beathii	endemic to Cameron area, extends into GGCHNM?
Fabaceae Astragalus castaneiformis	N AZ endemic
Fabaceae Astragalus cremnophylax var. hevronii	GC endemic

Plant Family and Species Name	Distribution Notes
Fabaceae Astragalus cremnophylax var. myriorrhaphis	GCendemic
Fabaceae Astragalus episcopus var. episcopus	endemic to MArble Canyon area/ VC
Fabaceae Astragalus episcopus var. lancearius	endemic to N AZ and S UT
Fabaceae Astragalus humistratus var. tenerrimus	probably endemic to GC rims
Fabaceae Astragalus lancearius	endemic to N AZ and S UT
Fabaceae Astragalus mokiacensis	endemic to N AZ and S NV
Fabaceae Astragalus pinonis var. atwoodii	endemic to AZ Strip
Fabaceae Astragalus preussii var. latus	endemic to N AZ and S UT
Fabaceae Astragalus straturensis	endemic to N AZ and S UT
Fabaceae Astragalus subcinereus	endemic to N AZ and S UT
Fabaceae Astragalus zionis	endemic to N AZ and S UT
Fabaceae Oxytropis oreophila	apparently a CP endemic
Grossulariaceae Ribes quercetorum	odd outlier from CA, but valid specimen
Lamiaceae Salvia davidsonii	NW AZ endemic
Lamiaceae Scutellaria potosina var. kaibabensis	East Kaibab monocline endemic
Onagraceae Camissonia exilis	endemic to N AZ and S UT
Onagraceae Camissonia gouldii	endemic to N AZ
Onagraceae Camissonia multijuga	endemic to S UT, S NV, and N AZ
Onagraceae Camissonia parryi	endemic to N AZ and S UT
Onagraceae Camissonia specuicola	endemic to GC region
Onagraceae Oenothera cavernae	nearly endemic to GC region
Orobanchaceae Castilleja kaibabensis	endemic to KP
Orobanchaceae Cordylanthus wrightii subsp. kaibabensis	endemic to KP
Plantaginaceae Penstemon laevis	endemic to N AZ and S UT
Plantaginaceae Penstemon linarioides var. viridis	AZ endemic
Plantaginaceae Penstemon pseudoputus	endemic to AZ Strip and S UT
Poaceae Imperata brevifolia	GC is an important refuge for this grass, which probably used to be more common and widespread
Polygonaceae Eriogonum corymbosum var. thompsoniae	endemic to AZ Strip and S UT
Polygonaceae Eriogonum darrovii	nearly endemic to the AZ Strip
Polygonaceae Eriogonum heermannii var. apachense	endemic to AZ, reaches its northern limit at GC
Polygonaceae Eriogonum heermannii var. sulcatum	endemic to GC region and S NV
Polygonaceae Eriogonum jonesii	endemic to areas around GC
Primulaceae Primula specuicola	CP endemic, reaches its souther limit in GC
Rhamnaceae Ceanothus martinii	reaches its souther limit on KP
Rosaceae Ivesia arizonica var. arizonica	endemic to GC region and S NV
Rosaceae Rosa stellata subsp. abyssa	endemic to GC region and S NV

Fickeisen Plains Cactus *Pediocactus peeblesianus* var. *fickeiseniae (*Backeberg) Kladiwa

This small, low-growing cactus species is found only on Kaibab limestone soils on the southern Colorado Plateau. It occurs in small, isolated populations. On the Arizona Strip, it occurs between Mainstreet Valley to the west and House Rock Valley to the east. South of the Colorado River on the Plateau, it occurs from Cataract Canyon east to Gray Mountain and the Little Colorado River. It may be declining due to livestock grazing and drought, as well as non-native species invasion.

Kaibab Indian Paintbrush *Castilleja kaibabensis* N. Holmgren

This herbaceous perennial is endemic to the Kaibab plateau occupying rocky knolls, usually in the driest, most exposed sites in open meadows at 8200-9000 feet (Fig 4.1). It grows in fine silts and clays and rocky, gravelly meadow soils derived from weathered Kaibab limestone in the driest, most disturbed sites in open meadows (AGFD 2003). This paintbrush is remarkable in the variety of color variations it displays in the same population: pale orange, pale red, yellow, soft pink and dull white may all intermingle. *C. kaibabensis* blooms in July and August exhibiting the above mentioned array of colors.

This plant closely resembles *C. lineariaefolia* and *C. integra*, but differs in having bracts divided with fairly acute-tipped lobes and rounded tip, no white, wooly-hairs on stem, and flatter leaves (Grand Canyon National Park, online).

Kaibab Sedge *Carex curatorum* Stacey

This sedge is found only on the Colorado Plateau at elevations ranging from 900-1,300 m. It forms tufts, and droops elegantly at hanging gardens and along stream banks. It can be distinguished from similar Carex species by having easily dispersed seeds (achenes) and by not having sheaths and bases apparent from the previous years' growth (Ball and Rezinicek).

Fig. 4.1 Kaibab Indian Paintbrush, growing in the meadows near Deer Lake, Kaibab National Forest. Photo by Molly Joyce.

Fauna

Invertebrates

The proposed GGCHNM and surrounding area is one of the entomologically least-studied landscapes in the nation, with the primary entomological attention paid to butterflies. Waltz (1998) recorded 31 species of butterflies and skippers in 5 families on Mt. Trumbull to the west of GGCHNM. The butterflies of the North Kaibab Plateau have been investigated for several years by Mr. Richard Zweifle of Kanab, Utah, who reports that the most commonly encountered species include: *Colias eurytheme*, *Abeis nicippe*, *Plebejus melissa*, *Vanessa cardui*, *Nymphalis antiopa*, and *Junonia coenia*. Kaibab Plateau dragonflies also have received some attention: Stevens and Bailowitz (2009) report several dozen species in the region, with *Coenagrion resolutum* regionally restricted to perennial North Kaibab ponds.

Several endemic invertebrate species are known from the GGCHNM, particularly in and around North Canyon. Not only does that drainage support endangered Apache trout (*Oncorhynchus apache*), but also an endemic riparian *Nebria* (Carabidae) ground beetle, a new species of stonefly (being described by R. Baumann of Brigham Young University), and a population of the North Rim endemic Schellbach's Fritillary (Nymphalidae: *Speyeria hesperis schellbachi*). Meadows at the headwaters of that drainage also support the endemic Kaibab Variable Tiger Beetle (*Cylindera terricola kaibabensis*), which is tightly restricted to a few North Rim meadows. The endemic Kaibab Monkey Grasshopper (Eumastacidae: *Morsea kaibabensis*) occurs along the east flank of the Kaibab uplife in middle elevation meadows, but is rarely encountered. These and likely other endemic invertebrate taxa exist on and around the proposed monument.

Kaibab Variable Tiger Beetle Carabidae: *Cylindera terricola kaibabensis* Johnson

Adults of this elusive tiger beetle are 8-15 mm long and the body is long and thin with relatively parallel outer elytral (first pair of wings) edges (Fig. 4.2). Colors range from copper-green to blue-green with narrow, yellowish maculations (markings) that are usually connected. This subspecies is restricted to a few grassy meadows on the Kaibab Plateau of northern Arizona (Stevens and Huber 2004, Pearson, et. al. 2006).

Adults are active during the warm days of summer and feed on soft-bodied invertebrates. They wait, motionless and alert, but ready to sprint after passing prey. These beetles are easily alarmed by movement or vibrations, and fly when approached to within about 2.5 m (Stevens, pers. observations). Their flight is erratic and they usually land in a clump of grass, disappearing immediately.

Larval Kaibab Variable Tiger Beetle have not been studied but are likely similar to those of other members of the subgenus *Cylindera*. General characteristics include a large, flattened head, massive mandibles, and a pronounced dorsal hump on the thorax. They construct vertical burrows in which they wait for passing prey (primarily other invertebrates; Pearson et al. 2006).

Fig. 4.2 Kaibab Variable Tiger Beetle. Photo by Jenn Chavez.

Kaibab Monkey Grasshopper Eumastacidae: *Morsea kaibabensis* (Rhen and Grant) Otte

Monkey grasshoppers are distinguishable from katydids and crickets by their short stubby antennae and oddly long, gangly legs (Fig. 4.3). The head is long and set at an angle to the thorax. Many of these species are brightly colored, while some resemble leaves or sticks. The hind legs are thin and elongate, with distinctive spines on the lower half of the tibiae. At rest, many species sit with their hind legs splayed out sideways. The antennae are shorter than the front femora and the majority of species are wingless. Their family feeds on a variety of plant types ranging from grasses and sedges to desert shrubs and ferns.

Fig. 4.3 Kaibab Monkey Grasshopper, *Morsea kaibabensis*). Photo by Jenn Chavez.

The type locality for this species is Coconino County, Arizona on the east-facing escarpment of the Kaibab Plateau, and they have been taken as far south as near Highway 89A at about 1800 m, half way up onto the Kaibab Plateau. The habitats in which they have been captured were dry meadows in pinyon-juniper woodlands.

Persephone's Darner Aeshnidae: *Aeshna persephone*

The larvae of this large darner dragonfly inhabit ponds and slow-moving streams, and move about by pumping water backwards through their abdomens. The larvae are elongate, buff-colored, and have a conspicuous extendable lower mandible.

Adult Persephone's Darners are large, robust dragonflies two wide, yellow-green lateral stripes on the thorax, and having lateral blue spotting very small to absent on abdominal segments 7-10 (Fig. 4.4). The cerci are palmate and wedge-like. Persephone's Darner hindwing length varies from 48-52 mm, and their total body length varies from 72- 75 mm. Persephone's Darner is similar in appearance to the slightly smaller *Aeshna palmata* Hagen, and within their range of overlap they can be difficult to separate. *A. palmata* has a hindwing length of 43-47 mm, a total body length of 67-70 mm. It has narrower yellow to blue-green stripes on the thorax and on the abdomen the lateral blue spots extend into segments 7-10. Also, its cerci are palmate (Needham et al. 2000).

Fig. 4.4 Persephone's Darner. Photo by Doug Danforth.

Persephone's Darners fly mostly in the late summer and fall and are likely to have just one generation per year. The larval stage has not been well studied, but they probably occupy slow portions of desert mountain streams, where they prey on soft-bodied insects, tadpoles, and perhaps small fish. The adults are notoriously difficult to catch because they fly erratically, follow shadow lines as they patrol, and sometimes rise 10-15 m above the ground (Stevens, pers. obs.).

Persephone's Darner is endemic to the American Southwest and northwestern Mexico. On the southern Colorado Plateau, it has been detected between 1200-2300 m elevation. Persephone's Darners have yet to be found on the Kaibab Plateau, but are found south in Grand Canyon and immediately to the north in Grand Staircase Escalante National Monument in Kane County, Utah. Therefore, they are expected to occur on the North Kaibab Plateau. Their rarity on the Kaibab Plateau may primarily be due to the natural scarcity of suitable habitat. This species has been found in and along partially shaded desert mountain streams, and also has been documented in open riparian settings near perennial streams. It has rarely been reported away from water in this region, and is almost always confined to middle elevation canyons with permanent or semi-permanent flow.

Kaibab Indra Swallowtail Papilionidae: *Papilio indra kaibabensis* Bauer

A large, iconic black swallowtail, the adults of this regionally endemic subspecies have constellations of sky blue dots arranged in tight patches in a band on both the upper and lower side of the hind wing, and a light yellow band on the underside of the hind wing (Fig. 4.5). This subspecies occurs in mountainous terrain, and is largely restricted to inside Grand Canyon just below the rim; however, it occasionally occurs on to the south of Grand Canyon and has been detected as far to the southeast as Cameron, Arizona (Garth 1950; Stevens 2012). Previously reported as flying in mid-summer, it recently has been found near Saddle Mountain as early as mid-April. Mature caterpillars are large and black and light coral banded, with yellow spots. They feed on members of the parsley family.

Fig. 4.5 Kaibab Indra Swallowtail. Photo by Tom Cheknis.

Grand Canyon Ringlet Butterfly: *Coenonympha tullia furcae* Barnes and Benjamin

This small, buff-colored satyr butterfly has a single dark eyespot near the upper corner of the forewing, and a mottled faun and white pattern on the underside of the hind wing (Fig. 4.6). It flies in abundance in June along the South Rim of Grand Canyon, and occasionally wanders into the forests to the south. It flies in a highly erratic fashion through forest glades, providing only a brief glimpses to those aware of it. The species to which it belongs is widespread throughout the West, but is highly variable regionally, with numerous subspecies described (Garth 1950). Mature caterpillars are small and inconspicuous, and are reported to feed on grasses.

Fig. 4.6 Grand Canyon Ringlet butterfly. Photo by Tom Cheknis.

Schellbach's Northwestern Fritillary Nymphalidae: *Speyeria hesperis schellbachi* Garth

This is a large, showy, rust and black brush-footed butterfly, with dark axes on the upper wings and silver spots on the underside of the hind-wing (Fig. 4.7). It is found only along the North Rim of Grand Canyon and the East Rim of Kaibab National Forest (Garth 1950). Like all fritillaries, its larvae feed on violets. They emerge from the egg in autumn and immediately go into winter dormancy, not beginning feeding until the following spring.

Fig. 4.7 Schellbach's Northwestern Fritillary butterfly. Photo by Tom Cheknis.

FISH

Apache Trout Salmonidae: *Oncorhynchus apache* (Miller)

Native fish no longer naturally occur on the Kaibab Plateau; however, Apache Trout were translocated into North Canyon Creek nearly a century ago, and that population has persisted. The North Canyon Apache Trout population has remained pure, and has been used to restock streams in central eastern Arizona in which hybridization with introduced rainbow trout took place.

Herpetofauna

The amphibians and reptiles of the GGCHNM include 8 amphibians and 35 reptiles. The amphibian species primarily occupy wetland habitats, while most of the reptiles are upland taxa, although Terrestrial Garter Snakes are commonly encountered in ponds and along slow-moving streams. Tiger salamanders are also present (Fig. 4.8)

Arizona Tiger Salamander: Ambystomatidae: *Ambystoma mavortium nebulosum* Hallowell

The Arizona Tiger Salamander is found above about 1500 m on the southern Colorado Plateau, where it occurs in ponds (Fig. 4.8). It can grow to more than 30 cm long and is dark gray or olive in color irregular yellow or greenish markings. It can be confused with the widely-introduced barred tiger salamander ("water dogs"; *A. m. mavortium*), which has decimated native salamander populations. Neotenic larvae and gilled adults (branchiates) can remain aquatic, and often are cannibalistic. Tiger salamanders are predatory, and feed on a wide array of aquatic and riparian invertebrates and small vertebrates (Brennon and Holycross 2006).

Fig. 4.8 Tiger Salamander. Photo by Larry Stevens.

Adult tiger salamanders wander long distances away from perennial ponds on the North Kaibab and elsewhere, particularly during the rainy season. However, as amphibians, they must return to ponds to breed. Both normal and branchiate adults can breed, in either late winter or rarely during the summer monsoon period. Eggs are laid singly or in small masses and often are attached to underwater sticks or vegetation. We have found their eggs under the ice in February in ponds on the North Kaibab, along with mature endemic Kaibab fairy shrimp (Brachinectidae: *Branchinecta kaibabensis* Belk and Fugate). Tiger salamander females can produce up to 2000 eggs each year, and the young hatch within about two weeks, and mature in about two months, unless conditions favor the young remaining in the neotenic form.

Avifauna

We found evidence of at least 121 bird species on and around the North Kaibab and Tusayan Districts. Whereas the bird fauna of Grand Canyon is rather well known (e.g., Brown et al. 1987), that of the Kaibab has been less thoroughly documented. Regional avian studies that provide good background information include those by: Birek et al. 2009; Chambers and Kalies 20112; Blake's (1981) work on 92 bird species he detected on and around Mt. Dellenbaugh; Huey (1939); Rasmussen 1941; Behle 1943; Behle et al. 1958; Wauer and Carter 1965, 1967; the Arizona Breeding Bird Atlas (2006); and our own observations.

The East Kaibab Monocline serves as a major raptor migration route across Grand Canyon. Hawk Watch International and Grand Canyon National Park partnered for 17 years, documenting the intensity of raptor migration at Yaki and Lipan Points on the South Rim (http://hawkcount.org/month_summary.php?rsite=578). The hawk migration takes place from late August into early November. The most common hawks observed are: Sharp-shinned, Cooper's, Red-tailed, Swainson's Hawks, American Kestrel, Osprey, Northern Harrier, with Golden and Bald Eagle, Peregrine and Prairie Falcon, Ferruginous Hawk, Northern Goshawk, and the endangered California Condor.

Northern Goshawk *Accipiter gentilis (*Linnaeus)

The Northern Goshawk is the largest accipiter in the nation. Possessing a long tail and broad rounded wings enables them to maneuver quickly through dense forests. This species is slate gray above and has dense gray barring on the chest. It has a dark gray head with a conspicuous light eyebrow, flaring behind the eye and separating the black crown from a variably gray back. Its barrel shaped chest is white with fine gray barring; appearing light gray at a distance. The tail is gray with black transverse bars. Eye color ranges from yellow, orange, to fiery red in older birds (gray in nestlings). When hunting it perches silently then descends rapidly, taking prey as small as squirrels and as large as grouse, crows, and rabbits.

Northern goshawks occur year-round in the mountains of Arizona. They typically nest in mature or old growth forests, usually above 1800 m, and often select larger tracts of forests. The population on Kaibab Plateau exhibits one of the highest breeding densities known. Their nest is a bowl of sticks lined with bark and greenery high in a tree. These nests contain 1-5 bluish-white eggs (Squires and Reynolds 1997). The female incubates the eggs for 28-38 days and then broods the nestlings, which are fed by both the male and the female. The young begin flying at 35-42 days and become independent at about 70 days (Arizona Game and Fish Department 2013).

California Condor *Gymnogyps californianus* (Shaw)

California condors are one of the rarest birds in the world, numbering about 425 worldwide, with about 219 individuals living in the wild. They are the largest bird in North America, having a wingspan of nearly 3 m and weighing up to >10 kg. Adults are primarily black except for triangle-shaped patches of bright white underneath their wings. These patches are visible when condors are flying overhead and are a key characteristic to positive identification. Males and females are identical in size and plumage. The bare heads of condors are grayish-black as juveniles and turn a dull orange-pink as adults. Condors are members of the New World vulture family and are opportunistic scavengers, feeding exclusively on dead animals such as deer, cattle, bison, rabbits, and large rodents.

Condors do not build nests; instead, an egg about 5 inches in length and weighing around 10 ounces is deposited on bare ground in caves and rock crevices. They typically lay a single egg every other year. The egg hatches after 56 days of incubation and both parents share responsibility for incubation and for feeding the nestling. Young condors leave the nest when they are 5 to 6 months old.

Condors were extirpated from the region early in the twentieth century, and nearly went extinct. However, they were brought back through a captive breeding program and, beginning in 1995, were re-released into the wild. At present, about 73 condors soar over northern Arizona and southern Utah. Many of the condors from northern Arizona and southern Utah frequent Grand Canyon, especially during the summer. They come from all four captive breeding locations. But more importantly, a number of them come from wild nest caves in and around the Grand Canyon. A tag chart and condor update is online at: http://www.nps.gov/grca/learn/nature/california-condors.htm#CP_JUMP_720673.

The leading cause of condor death in the wild is lead poisoning from spent lead ammunition. Each year 45-95% of the condor population tests positive for lead exposure. A recent press release from the Peregrine Fund reported that trapping and testing results revealed 55 of the 73 condors tested over the winter and early spring showed unsafe levels of lead in their blood. Nearly one-third of those birds had extreme, life-threatening toxicity levels. Over the years, lead poisoning has accounted for just over 50 percent of all condor deaths. As part of an effort to reduce lead exposure in condors, AGFD has provided free non-lead ammunition to big game hunters in Units 12A, 12B, 13A, and 13B (the areas condors frequent most during the hunting season). Hunters responded with 80 to 90 percent voluntarily using non-lead ammo or removing their gut piles to benefit condors (Arizona Game and Fish Department online).

MAMMALS

Like most other faunal groups, the mammals of the GGCHNM region are known from only a few scientific studies. Hoffmeister and Durham (1971) and Hoffmeister (1986) listed the mammal species of the region, and distribution and biogeographic anomalies in the region. At present, at least 79 mammal species are known in the GGCHNM. These include 19 species of bats, numerous rodents, Desert Mule Deer and hybrid Bison, as well as numerous meso-predators, such as Long-tailed Weasel, Gray Fox, Coyote, Skunk, Raccoon, Bobcat, and Mountain Lion, and the rare American Black Bear. On the GGCHNM south of Grand Canyon, collared peccary are beginning to colorize the Coconino Plateau. Several predacious species, such as Plains Gray Wolf (*Canis lupus youngi*), Jaguar (*Felis onca*), Grizzly Bear (*Ursus arctos*) that once dominated the food web of the region, have been extirpated or driven to extinction creating significant disruptions to trophic processes in GGCHNM ecosystems.

Fig 4.9 Desert Mule Deer.

Desert Mule Deer Cervidae: *Odocoileus hemionus* Rafinesque

Ungulate populations have been of enduring subsistence and economic interest to residents and game managers (AGFD) of the GGCHNM region (Fig. 4.9). Desert Mule Deer can grow to be exceptionally large on the Kaibab Plateau. Lack of summer water probably prevents mule deer from remaining at low elevations during the summer; however, they use snow as a water source during the winter, following it downslope as it falls and upslope as it melts. Bostick (1988b) reported two historical cycles of deer population growth on the southern Shivwits to the west of GGCHNM, which occurred with the onset of intensive livestock grazing and the extirpation of native predators. The Kaibab deer population increased in the 1910s and crashed later that decade, the increased again in the 1940s and crashed in the 1950s, and then increased again in the 1960s. Therefore, including the mule deer population rise and crash recorded by Rasmussen (1941), at least three population cycles of desert mule deer occurred over the past century. The primary forage for mule deer on southern GGCHNM points and canyons is cliff rose, which is closely cropped throughout the year. Bostick (1988b) concluded that high deer population levels about 35 ± 10 years (prior to 1988) caused a die-off of cliff-rose and sagebrush on the Parashant grazing allotment.

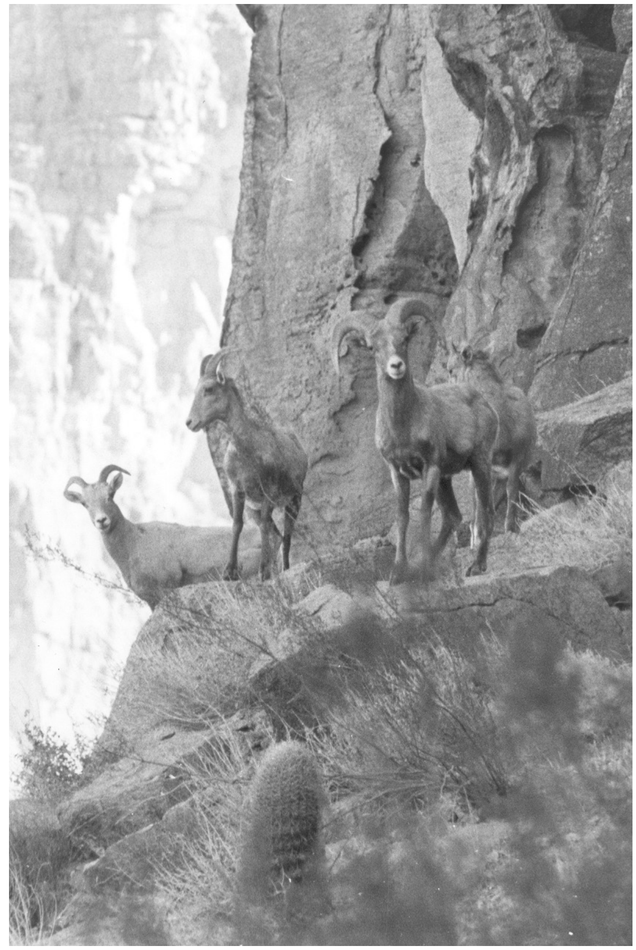


Fig. 4.10 Bighorn sheep perched alongside a cliff face, Grand Canyon National Park. Photo by Larry Stevens.

Desert Bighorn Sheep Bovidae: *Ovis canadensis nelsoni* Merriam

Like pronghorn, desert bighorn sheep were essentially extirpated from the Arizona Strip by the early 1900s, except in lower Kanab Creek and along the southern Grand Wash Cliffs (Fig. 4.10). Bighorn sheep populations are believed to have been more abundant and more widely distributed historically. These animals are highly valued by the public for wildlife viewing, photography, and hunting opportunities. Since the late 1970s, the BLM and the AGFD have been cooperatively working to re-introduce desert bighorn sheep. Several of these re-introduction efforts have been successful (U.S. Bureau of Land Management 1997). Populations of desert bighorn occupied the Virgin and Beaver Dam Mountains and the Grand Wash Cliffs, and the total population on the Arizona Strip exceed 500 on BLM administered lands. Augmented water sources (guzzlers) may have helped some of these translocation efforts.

Pronghorn Antilocapridae: *Antilocapra americana* Ord

Pronghorn occur across western US, with ranges from 65 km^2 to 250 km^2 (Yoakum 1980). Pronghorn mostly range from 900 to 1800 m elevation, but move higher (to 2700 m) in summer in the Southwest. Arizona pronghorn make much more use of woodland and forest habitat than expected, but their use of these habitats is not well known.

Pronghorn require 0.75 - 1.5 kg of forage/day (dry mass) and up to 1 kg/d on the range (Severson and May 1967, Schwartz and Nagy 1976),and their diet is opportunistic and selective, taking browse year-round, with forbs dominant in spring and summer, and grasses used only in early growth periods (Autenreith 1978, Allen et al. 1984). The success of the pronghorn restoration program has allowed the AGFD to issue hunting permits during the past two decades.

The pronghorn population on the Arizona Strip has declined over the past 50 years, but it has been augmented over the past several decades by the Arizona Game and Fish Department (1978). Pronghorn on the Strip numbered 150-200 head by 1998. Pronghorn occurred on the GGCHNM and surrounding region until at least 1916 (Knipe 1944, Cox and Russell 1973). In 1965 55 Montana pronghorn were released on the Arizona Strip, but the success of the release was not apparent until 1974, when 11 animals were spotted during aerial surveys. The number had increased to 81 animals by 1977.

Kaibab Northern Pocket Gopher Geomyidae: *Thomomys talpoides kaibabensis* Goldman

This is a small species of pocket gopher and the sub-species, *kaibabensis*, is distinguished by being smaller yet. A prominent black patch around and behind each ear and chestnut coloring on top of the head distinguish it.

This gopher lives on the Kaibab plateau, in the soils of high mountain meadows surrounded by Ponderosa pine or spruce-fir. In those meadows grow a variety of grasses, weeds and shrubs providing food for at least part of the year. Gestation period is about 18 days, eyes and ears of young do not open until about 26 days after birth. Adult fur grows in at about 3 months of age (Hoffmeister 1986).

Kaibab Squirrel Sciuridae: *Sciurus aberti kaibabensis* Merriam

This tassel-eared squirrel lives naturally only on the Kaibab Plateau of northern Arizona. It is distinguished from the conspecific Abert's or Tassel-Eared Squirrel that lives south of Grand Canyon by its blackish belly and a tail that is white above and a bit shorter. It was once considered to be a fully different species, but is now considered to be a subspecies of Sciurus aberti, the Tassel-eared Squirrel. There is usually some chestnut brown on their head and back. The ear tufts grow longer with age and may extend 1-2 inches (25-50 mm) above the ears in winter, but are much shorter in summer (Hoffmeister 1986).

Habitat for this squirrel is the ponderosa pine forest where it lives and builds its nests of pine needles and twigs. It feeds on seeds, bark, and twigs of the trees, as well as on subterranean mushrooms. This squirrel's primary food sources are ponderosa pine seeds from pine cones. Young squirrels are born in late spring to early summer (Hoffmeister 1986). The Kaibab squirrel is an excellent example of allopatric speciation – post-Pleistocene colonization and isolation allowed the two lineages to drift apart.

Mountain Lion: Felidae: *Puma concolor concolor* (Linnaeus 1771)

Mountain lions are large, widespread, solitary cats and are top predators(Fig. 4.11. They are found across the New World, most often in topographically complex terrain. Mountain lions are sit-and-wait predators, feeding

Fig. 4.11 Mountain Lion photo courtesy of http://www.flickr.com/photos/dbarronoss/ / CC BY-NC-ND 2.0.

on a wide array of mammals, birds and other vertebrates (Hoffmeister 1986). Their populations are declining throughout their range, particularly because of overhunting, and mountain lions have been largely eliminated from portions of their native range, such as southwestern Arizona and in the eastern United States (except in Florida, where it is an endangered subspecies). The GGCHNM region is the last stronghold for mountain lions in Arizona. Here, they feed on deer, elk, bighorn sheep, and smaller mammals, including other predators. Mountain lions generally kill one large prey animal every 10 days. Male lions are larger than females, and can reach a mass of 150 lbs. Both sexes are solitary, highly territorial, and require large home ranges: male collared lions in the Grand Canyon region occupied 124 to 185 mi^2 ranges, while females occupied 76 to 172 mi^2. Mountain lions wander widely within their territories, and individuals have been documented traversing Grand Canyon to hunt on the rims. Individuals can live for more than 10 years, but life spans are usually much shorter due to hunting pressures. Female mountain lions can breed at 3 years of age, and can produce three spotted young, which gradually lose their spots but remain with their mother for 18 months. Year-round hunting of these top predators is permitted by the Arizona Game and Fish Department (2016), and 250 and 350 animals are killed each year. About 12% of those killed are taken by predator control agents.

American Bison Bovidae: *Bison bison* Linnaeus

Bison are not native to Arizona, arriving in 1906 when Charles Jones brought them to the Kaibab Plateau in northern Arizona and cross-bred them with cattle (Fig. 4.10). He hoped to create a more robust breed, the "cattalo". When this effort failed the herd was sold to and maintained by the state of Arizona at House Rock Valley Wildlife Area, east of the Kaibab Plateau (AZ Game and Fish Department 2015). As a result of drought beginning in the late 1990s the herd began to migrate back to the Kaibab plateau. Today there are over 400 bison on the plateau, mostly in Grand Canyon National Park (The Guide, 2015). These large herbivores are impacting water sources, devouring and trampling sensitive vegetation and compacting fragile soils. Grand Canyon National Park is working closely with state and federal managers to attempt to reduce the bison's negative impacts (The Guide 2015).

Fig. 4.12 Bison at the entrance to Grand Canyon National Park's North Rim. Photo by Jeri Ledbetter.

Fire And Forest Health

Much of the North Kaibab is a ponderosa pine forest on which fire suppression, grazing and logging have altered forest structure and composition for more than a century. The pre-Euro-American fire frequency was high, but fire suppression has allowed doghair thickets of young pines to proliferate, and fuel loads to accumulate. Although this appears to be the normal condition for ponderosa pine forests throughout the Southwest, the North Kaibab supports rare stands of old growth forest, which support many characteristic species and are worth protecting from anthropogenically intensified fire threats.

A Living Map of the Biota of the Proposed Monument

We present a living map showing examples of the biota that are of special biological and cultural significance to the proposed Grand Canyon Heritage National Monument (Fig. 4.13). Explore this map online at: http://arcg.is/1SOmiyj.

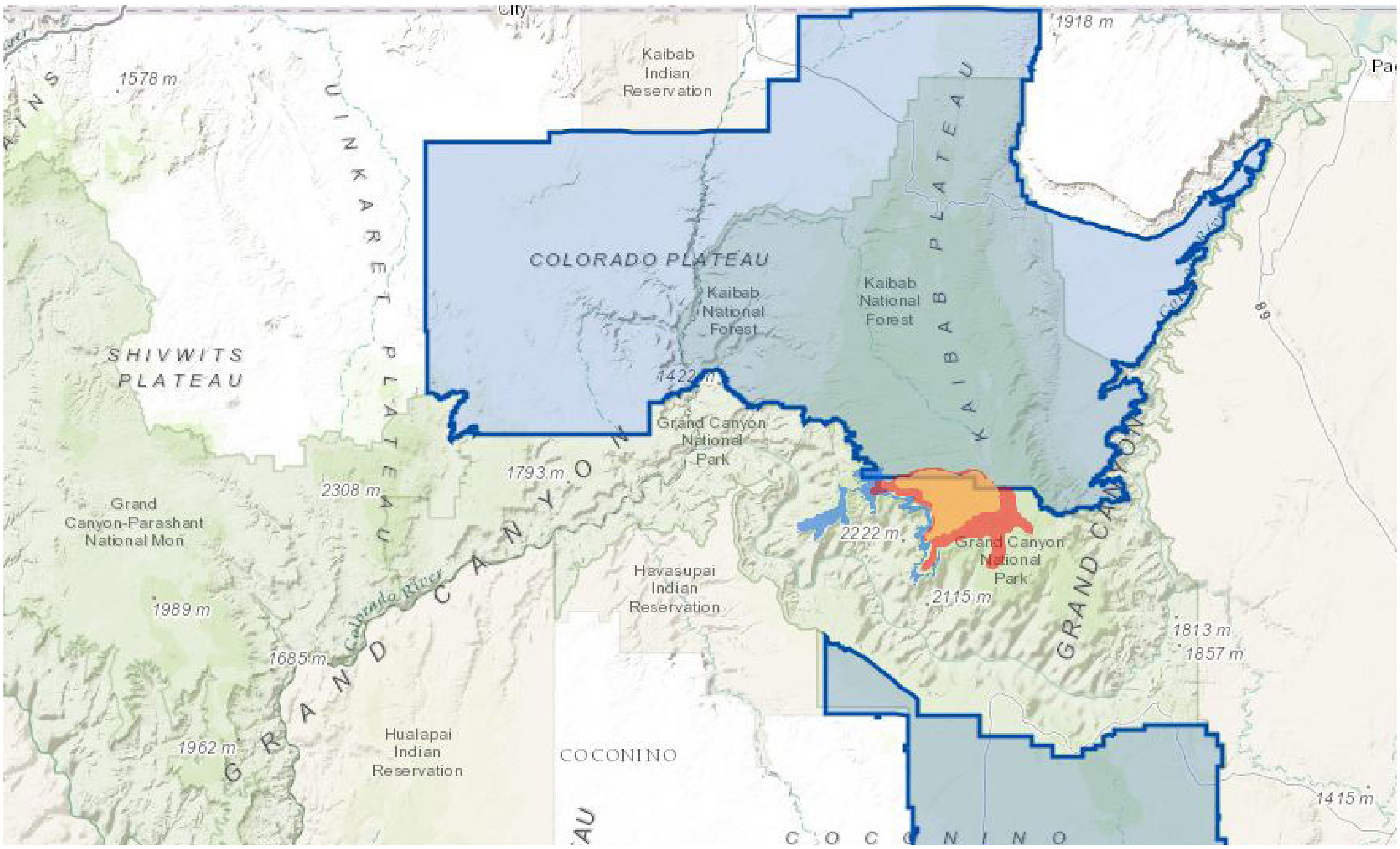


Fig. 4.13 Range map of Bison within the proposed Grand Canyon Heritage National Monument. Map produced by Jeff Jenness.

CHAPTER 5

ARCHAEOLOGY OVERVIEW

KIM SPURR AND JAMES COLLETTE

Introduction

This chapter is a brief archaeological overview of the proposed Greater Grand Canyon Heritage National Monument and the Grand Canyon at large. While the Grand Canyon is a substantial barrier to travel, it was also a corridor and crossroads, with many cultures and individuals calling it home or drawn to the natural splendor of its deep chasms, flowing waters, and forested rims. Culturally speaking, all roads led both to and from the Grand Canyon; for Spanish explorer Garcia López de Cardenás it was an impenetrable abyss; for the Hopi and Zuni peoples, a sacred place of emergence; for the Navajo, a refuge from the merciless campaigns of Kit Carson; and for the Pai and Southern Paiute, an ancestral home. Mormon colonizers quickly recognized its unmatched wonder and commercial promise.

The Grand Canyon, however, does not exist as an inverted island, removed from the embrace of surrounding side canyons, plateaus, and tiered benches. It is an interconnected system of resources that ranges from low desert to alpine forests—a cascade of life zones nearly unparalleled in the world. The proposed GGCHNM encompasses not only a hydrologic system, but a cultural homeland that was inexorably linked to the Canyon's bounty and sacred sense of place. In this chapter, we summarize the general archaeological chronology of the proposed monument, with an emphasis on three pre-contact cultures that resided within its boundaries: the Southern Paiute, the Havasupai, and the Hualapai. A measure of detail is also afforded to the Spanish explorers and the pioneering efforts of the Mormon colonies, those who followed The Church of Jesus Christ of Latter-day Saints.

For the purposes of this chapter, we will use a modification of the chronologies presented in Table 2 of Fairley (2003), and Figure 4 in Geib (1996), shown here as Table 1. The culture history of the area has been divided by anglo archaeologists into five broad time periods: Paleoindian (11,500-8000 B.C.), Archaic (8000-1000 B.C.), Early Agricultural (1000 B.C.-A.D. 400/500), Formative (A.D. 400/500-1300), Protohistoric (A.D. 1300 to 1500/1550), and Historic (A.D. 1500/1550 to the modern era). The Archaic Period can be further sub-divided into Early (8000-5000 B.C.), Middle (5000-3000 B.C.), and Late (3000-1000 B.C.). Likewise, the Formative Period has been divided by some researchers into Early (A.D. 400/500-900/1000) and Late (A.D. 900/1000-1300).

These archaeologists have also used a roughly analogous sequence referred to as the "Pecos Classification," named after an annual conference held at Pecos, New Mexico and other locations since 1927 (Kidder 1927). Although the Pecos "stages" originally had connotations of cultural progression from hunter-gatherers to more sedentary, agriculturally-based societies, it is now primarily used to order sites within a temporal framework. Date ranges should be considered approximate; variation occurs between both regions and analysts.

This culture history begins with the Paleoindian Period and ends with the start of the 20th Century, during the interval between the creation of Grand Canyon as a Forest Reserve (1893) and the establishment of Grand Canyon National Monument (1908). The story of Grand Canyon National Park and its surrounding environs during the modern era is presented elsewhere in this document. Seminal overviews that encapsulate the culture history of the greater Grand Canyon region include Altschul and Fairley (1989) and Ahlstrom et al. (1993).

Table 5.1. Chronology (after Fairley 2003:Table 2, and Geib 1996: Figure 4).

<table>
<tr><th colspan="2">Temporal Periods</th><th>Pecos Stages</th><th>Date Range</th></tr>
<tr><td colspan="2">Paleoindian</td><td></td><td>11,500-8000 B.C.</td></tr>
<tr><td rowspan="3">Archaic</td><td>Early Archaic</td><td></td><td>8000-5000 B.C.</td></tr>
<tr><td>Middle Archaic</td><td></td><td>5000-3000 B.C.</td></tr>
<tr><td>Late Archaic</td><td></td><td>3000-1000 B.C.</td></tr>
<tr><td></td><td>Early Agricultural</td><td>Late Archaic-Basketmaker II</td><td>1000 B.C. - A.D. 400</td></tr>
<tr><td rowspan="4">Formative</td><td rowspan="2">Early Formative</td><td>Basketmaker III</td><td>A.D. 400-700</td></tr>
<tr><td>Pueblo I</td><td>A.D. 700-900</td></tr>
<tr><td rowspan="2">Late Formative</td><td>Pueblo II</td><td>A.D. 900-1100</td></tr>
<tr><td>Pueblo III</td><td>A.D. 1100-1300</td></tr>
<tr><td colspan="2">Protohistoric</td><td>Pueblo IV</td><td>A.D. 1300-1500/1550</td></tr>
<tr><td colspan="2">Historic</td><td>Pueblo V</td><td>A.D. 1500/1550-present</td></tr>
</table>

Paleoindians

The Paleoindian Period begins with the first entry of humans into the region, and overlaps with the occurrence of species of megafauna that were probably an important food source for early peoples. For this reason, Paleoindians have traditionally been defined as big-game hunters with large mammal associations. These roving bands of hunter-gatherers would undoubtedly have also utilized other plant and animal resources at their disposal, but most of our information about this period on the Colorado Plateau derives from finds of isolated projectile points suitable for hunting of megafauna, such as mammoth and bison. By at least 9,000 BP the lifeway transitioned to an Archaic pattern of broad spectrum foraging (Geib 1996; Schroedl 1991).

While evidence for Paleoindian use of the proposed GGCHNM is scant, there is a growing body of evidence for Paleoindian and very early Archaic occupation of what Hollenshead (2007:3) called the "Greater Grand Canyon Region," or GGCR. Typically, the most common evidence for a Paleoindian presence in the region consists of fluted projectile points—primarily Clovis and Folsom. Copeland and Fike (1988) summarize Clovis and Folsom points found in southwest Utah, but the same point types have been recovered from the greater Grand Canyon region (Hollenshead 2007). North of Grand Canyon-Parashant National Monument, a Clovis point fragment was found at Sullivan Canyon (Miller 1978:35), and Schroeder (1961:74) mentions a "Plainview-like" point from a curated collection from the Shivwits Plateau.

Within Grand Canyon National Park (GRCA), Altschul and Fairley (1989:89) cite "an unsubstantiated report of Paleoindian points occurring along the North Rim in the vicinity of Tuckup Canyon," a canyon that cuts into the southern Kanab Plateau on the west side of the proposed GGCHNM. A Clovis fragment was found near Desert View, and a partial Folsom point was collected in the area of Little Nankoweap Canyon (reported in Hollenshead [2007:18] as being "identified by B[ruce] Huckell in 1993"). The Desert View point was fashioned from chert derived from the Chuska Mountains along the Arizona-New Mexico border, suggesting that either the finished point or raw material was brought or traded-in to the area; if the former, it may indicate a wide-ranging annual round by hunter-gatherers of that period. An overview of other Paleoindian points found in areas tangential to the Grand Canyon can be found in Lyndon (2005).

There is more artifactual evidence for regional use during the transition between the Paleoindian and the earliest stages of the Early Archaic. In a 1997 study, Melissa Schroeder found that 4% of the projectile points identified as Paleoindian or Archaic within Grand Canyon dated to the late Paleoindian Period (Schroeder 1997). This interval is exemplified by the appearance of shouldered and stemmed projectile point types, such as Lake Mohave, Silver Lake, and—somewhat later in time—Bajada/Jay. Points that belong to the "Stemmed Point Tradition" have been found within the Park on the Kanab Plateau and Tuckup Canyon in the western part of Grand Canyon (Huffman et al. 1990), and to the east near Mather Point, the Hilltop Site, Grandview, Buggeln picnic area, Point Sublime, Hitson Tank, Rowe Well, and Shoshone Point Road (Hollenshead 2007; Schroeder 1997) plus other locations in the GGCR. MacWilliams et al. (2006:98) reported three stemmed points, although they were not identified to specific type.

Archaic

The Archaic is generally viewed as a hunting-gathering lifeway that developed after the extinction of the Pleistocene megafauna and the evolution of post-glacial environments. During this time, plant gathering and hunting of smaller, modern fauna took on increased importance. On the southern Colorado Plateau, the Archaic is best represented in sheltered settings (see Geib 1996 for a summary), although open artifact scatters of stone tools and flake waste are not uncommon.

Based on dated occupations from surrounding regions, the Archaic period in the region probably extended from about 8,000 to ca. 1000 B.C. Sometime in the last millennium B.C., corn and squash may have been introduced to the region. The time range can be usefully partitioned into three intervals: Early, Middle, and Late. The three Archaic periods are defined, to a greater or lesser degree, by changing material traits, such as sandals and projectile points, stylistic differences related to rock art, and evolving ways in which hunter-gatherers used and moved about the landscape.

Various Archaic cultures, traditions, and complexes have been developed for the Southwest, but most are based on sites and finds from areas off of the Colorado Plateau and far from the project area (see Moffitt and Moffitt 2004:11-15 for a recent summation). The most applicable of the traditional cultures/traditions to the proposed GGCHNM are the Pinto Basin Culture, first defined by Campbell and Campbell (1935), and the Oshara Tradition, originally described by Irwin-Williams (1973). Broadly speaking, the two traditions reflect early aspects of the Archaic from the west (Pinto) and east (Oshara) regions of the Southwest. The age range of Pinto points continues to be debated, but some argue for a long cultural continuum that derives from Lake Mohave-type assemblages. Interestingly, "Pinto points are the predominate lithic artifact form representing the Early Archaic period in GRCA" (Moffitt and Moffitt 2004:13), with 27 having been documented in the Park as of 2004—25 on the South Rim alone. The Bajada/Jay points, previously mentioned, typify the namesake Bajada and Jay phases of Irwin-Williams' Oshara Tradition—the two earliest phases of this sequence. Depending on the author/analyst, Bajada/Jay points are included in either discussions of the terminal Paleoindian period, or the Early Archaic.

Many Archaic points are fashioned from local cherts, such as Kaibab chert, but rhyolite and obsidian points are also represented, made from raw material gathered from the San Francisco Volcanic Field in northern Arizona.

Whatever their absolute position on the prehistoric timeline, clearly there is a profusion of points being used in the GGCR by the Early Archaic. Aside from shouldered, stemmed and lanceolate points, there is also a sequence of corner- and side-notched points that appear during this time period. In fact, Phil R. Geib and others have proposed a Northern Colorado Plateau (NCP) sequence that might better fit the kinds of point diagnostics found in the region (see Holmer 1978). The NCP sequence has its roots in the so-called Desha Complex defined from excavated shelters and caves in southern Utah and northern Arizona (e.g., Lindsay et al. 1968; Lindsay 1969). Determining whether the sequence can be applied to the proposed GGCHNM area will require much more work—ideally in well-dated, stratigraphic contexts within sheltered settings.

It is possible that the most applicable of the Early Archaic point traditions to the GGCHNM is the Pinto Basin Culture, first defined by Campbell and Campbell (1935), and typified by the namesake Pinto projectile point. Pinto points are the most common Early Archaic point style in the Grand Canyon area (Moffitt and Moffitt 2004:13).

Several large-scale surveys on or near the Grand Canyon-Parashant have reported Pinto points (e.g., Robertson and MacWilliams et al. 2006; Svinarich 2006; Teague and McClellan 1978; Wells 1991). Humboldt points, another possible early Archaic marker[1], are found nearly as often, as are what MacWilliams et al. (2006:89) call "large side-notched" points—such as Northern Side-notched, although some of these styles may be later in the Archaic sequence. Other diagnostics of the Early Archaic tend to be perishables, such as sandals, and are much more likely to be found in sheltered settings.

Identifying flaked stone artifacts that date to the Middle Archaic period is difficult, as most projectile point styles that might belong to this interval also overlap into the Early or Late Archaic (Altschul and Fairley 1989:Figure 31). In general, there is a fall-off in sites, artifacts, and radiocarbon-dated material on the Colorado Plateau during the middle phase of the Archaic. The "lull" may be attributable to a true population decline (see Berry and Berry 1986), but other scenarios have been offered (Geib 1996). Currently, there is little evidence for use or occupation of the GGCHNM area during this time period. For example, while 31% of the Paleo-Archaic artifacts from the Grand Canyon are Early Archaic, only 9% may date to the Middle Archaic (Schroeder 1997).

As is the case elsewhere on the Plateau, there is much greater evidence for use during the Late Archaic in the region. In the Grand Canyon, for example, 50% of all paleo-Archaic sites and isolated finds date to this period (Schroeder 1997). The most frequently encountered projectile point from the Late Archaic is Gypsum (Holmer 1978), a contracting stem point that is found in the Grand Canyon interior, and in adjacent monuments, such as Grand Canyon-Parashant (e.g., MacWilliams et al. 2006; Robertson and MacWilliams 2006; Svinarich 2006; Teague and McClellan 1978). The earliest deposits at Antelope Cave, on the Arizona Strip, appear to date to the late Archaic (Janetski and Wilde 1989), and a putative pithouse that may date to the Late Archaic was found at the Arroyo Site along Kitchen Corral Wash buried beneath a Puebloan horizon (McFadden 2000).

The most spectacular Late Archaic material item, however—recognizable to the point of being an icon of Grand Canyon prehistory—are animal figurines made of split twigs (Euler 1984). The so-called "split-twig figurines," fashioned in the form of antelope and deer, are found in Late Archaic contexts in sheltered settings—most commonly, limestone solutions caverns within the Redwall Formation. Figurines were reported as long ago as the 1930s (Wheeler 1939, 1949), and Schwartz et al. (1958) described some initial finds within the Grand Canyon, but Robert C. Euler's work at Stanton's Cave along the Colorado River remains the most extensive investigation of what is now known as the Grand Canyon Figurine Complex (Euler 1984; Euler and Olson 1965; Schroedl 1977; see Coulam and Schroedl 2004; Emslie et al. 1995 for recent interpretations). In all, over 470 figurines have been found in GRCA, and, until recently, comprised the best data set for the Late Archaic in the Grand Canyon. Since then, numerous radiocarbon dates have been obtained from buried Archaic features along the Colorado River as part of studies related to the impacts of Glen Canyon Dam on downriver resources (Fairley 2003:57-63). Still, there is a great need for "information related to all aspects of the Late Archaic landscape…beyond the ritual use of caves" (Fairley 2003:137), and this is doubly so for preceding periods of the Archaic.

One promising avenue of study concerns Archaic rock art in the Grand Canyon, including a western variant of the Barrier Canyon rock art style (Schaafsma 1990). What has been called "an analogous but distinct style" (Moffitt and Moffitt 2004:14) called Grand Canyon Polychrome may date to the Late Archaic (Allen 1986, 1992; Christensen and Dickey 2006). Although there is some evidence that the style may pre-date the terminal Archaic, at least one radiocarbon date (Schaafsma 1990:215) was roughly contemporaneous with dated figurines and associated remains of the Grand Canyon Figurine Complex (Euler and Olson 1965; Schwartz et al. 1958). Mostrecently, Christensen and Dickey (2006) investigated 76 rock art sites on the South Rim of the Canyon and the adjacent Tusayan District of the Kaibab National Forest, which comprise an astounding 6308 pictographs and 1296 petroglyphs; the earliest examples appear to date to the Late Archaic.

[1]Humboldt shares general morphological characteristics with McKean points, which date to the late Archaic, and the two types can be confused. For example, Fairley states that most points identified as Humboldt in the Navajo-McCullough transmission line report (Moffitt et al. 1978)—a project that spanned much of the Arizona Strip—are McKean, and much later than a "Humboldt" assignment would suggest.

Early Agricultural (Basketmaker II) and Basketmaker III

The Early Agricultural Period (also referred to as the Late Archaic-Basketmaker II period) encompass the transition to agriculture from the Archaic hunting and gathering economy, followed by the initial establishment of more permanent settlements and development of a primarily agricultural lifeway. Habitations consisted of semi-subterranean pithouses and slab-lined storage features. As the name "Basketmaker" attests, the art of basket weaving predominated during Basketmaker II—an era that had not yet adopted the use of ceramic vessels. By Basketmaker III, however, pottery making was introduced and the bow and arrow replaced the atlatl as a means of projecting stone points. Most ceramic pots were plain gray or brown, but painted designs utilizing vegetal or mineral paint also began to appear.

The Archaic-Basketmaker transition (roughly 1000 B.C. to A.D. 700) may be the least understood cultural period in the Grand Canyon area. Even the timing of the period is not fully understood, as the temporal meaning of what "ends" the Archaic and "begins" the Early Agricultural Period is undergoing revision across the Colorado Plateau. The first use of maize on the southern Colorado Plateau is now believed to be between 2000 B.C. (Huber and Miljour 2004) and 1000 B.C. (Smiley 2002), but sites in the Grand Canyon region tend to lag in the introduction of corn by many hundreds of years. Davis et al. (2000) believed that there was evidence for corn agriculture in the Grand Canyon before 1000 B.C., based on maize pollen bracketed by two radiocarbon dates of 3160±60 B.P. and 4460±50 B.P., however, this claim has been disputed by Fairley (2003:84-85). Domesticated plants were probably being cultivated in the area by A.D. 500.

The question is not whether there was Early Agricultural use of the project area; there undoubtedly was, as Basketmaker remains have been recovered from sheltered sites in the region such as Cave DuPont near Kanab, Utah (Nusbaum 1922), Sand Dune Cave at the foot of Navajo Mountain (Lindsay et al. 1968), and Broken Arrow Cave (Talbot et al. 1999) on East Clark Bench near Big Water, Utah. Recent excavations for the Jackson Flat Reservoir Project south of Kanab uncovered numerous superimposed pithouses and related features dating between the Late Archaic and Pueblo II, affording an exceptional opportunity to study culture change through time (Heidi Roberts, personal communication, 2015). In the same general area, Basketmaker II-III remains were encountered at the Kanab Site, which also had a late A.D. 1000s domiciliary pithouse (Nickens and Kvamme 1981).

In the GGCR, the interval between 1000 B.C. and A.D. 700/800 is gradually being filled by additional radiocarbon dates (see for example Geib 2011), but some of the dates derive from wood charcoal samples and may be susceptible to the "old wood" problem, in which the dated sample can be several hundred years older than the target event (Fairley 2003:88-90; Smiley and Ahlstrom 1998). Nevertheless, the dates affirm an occupation during an interval that Effland et al. (1981:13) believed had "no direct evidence of human presence."

Formative (Pueblo I-III)

The ensuing Formative Period (A.D. 700-1300), which includes the Pecos Classification "stages" of Pueblo I-III, witnessed the greatest amount of cultural change in the shortest amount of time in settlement and subsistence practices, material goods, and possibly even cultural identity. As we have seen, the period can be divided into Early and Late, or partitioned into three Pecos "stages": Pueblo I (A.D. 700-900); Pueblo II (A.D. 900-1100); and Pueblo III (A.D. 1100 to 1250+ in the Grand Canyon, and up to A.D. 1300 elsewhere on the Plateau), with each period tied to changing styles in ceramics, architecture, site layout, and social patterning. The time ranges of these periods, however, are based primarily on cross-dated ceramic types from the east and southeast; ceramic types north and west of the Colorado River are not as well dated and may begin or end earlier or later than their eastern counterparts.

The Pueblo I-III Period is generally described as a time when populations became increasingly sedentary and dependent on agricultural crops such as corn, beans, and squash, and occasionally raised cotton. It is the most visible period on the ground as sites became larger and were occupied longer. The sites also became more architecturally complex, with above-ground masonry rooms, below-ground kivas, and site layouts that integrated storage, habitation and ceremonial functions.

The people of this time period are now commonly referred to as "Ancestral Puebloan." By A.D. 1000 at least three archaeological cultures bounded the Grand Canyon: the Kayenta tradition to the east (see Geib [2011] and Powell and Smiley [2002] for recent summaries regarding the "heartland" Kayenta), the Virgin tradition to the north (Aikens 1966; Lyneis 1995, 1996), and the Cohonina to the south (Cartledge 1979, 1987; Euler 1981; Hanson 1996; Hargrave 1938; Horn-Wilson 1997; James 1977; Jennings 1971; McGregor 1950, 1951, 1967; Moffitt 1998; Samples et al. 1991; Sullivan 1986).

Researchers have also defined an archaeological culture called "Cerbat," which appears to post-date the 12th Century (Cleeland et al. 1992). Although the particulars of Cerbat identity are still being debated (see Dobyns 1974; Hanson 1996; Reid and Whittlesey 1997; Simonis 1996), they may have been the successors to the Cohonina and the precursors of later Pai peoples, such as the Hualapai and Havasupai. Cerbat ceramics, in the form of Tizon Brown Ware (Dobyns and Euler 1958, 1985), can be found in the proposed GGCHNM, but is more common south of the Colorado River to the west.

By Late Pueblo I sites with ceramics within and south of the Grand Canyon tend to be dominated by San Francisco Mountain Gray Ware, primarily Deadmans Gray, with some decorated such as Kana-a Black-on-white, and intrusive red wares types, such as Deadmans Black-on-red. Schwartz et al. (1980) argued that the first Puebloan occupation of the Grand Canyon was by the Cohonina, rather than the Kayenta, and recent MNA/NPS Colorado River Corridor Archaeological Project (RCAP) excavations in the Canyon interior tend to support this view (Neff et al. 2016).

Whomever was in the Grand Canyon by A.D. 900-1000, they were apparently operating at a less intense or permanent level than later Pueblo II inhabitants. In contrast to Pueblo II/III masonry roomblocks, Pueblo I/II features within the inner Canyon are known only from possible pit structures (such as at UN-8 [Schwartz et al. 1980]), a roasting pit (found by Jones [1986] at Deer Creek), buried ceramics of that time period at Furnace Flats (Hereford et al. 1991), and a dated hearth in the same general area (Balsom and Larralde 1996). "With the exception of UN-8, and possibly UN-52…none of the Early Formative sites in the canyon has constructed features other than slab-lined cists, hearths and roasting pits" (Fairley 2003:92). In general, the Pueblo I peoples were using the inner canyon for logistical forays and short-term habitation as part of a subsistence round that included the South Rim, interior benches, and river-level lowlands.

On the South Rim of the Grand Canyon there are numerous sites with San Francisco Mountain Gray Ware and other Cohonina attributes that generally fall within the A.D. 600-1150 time frame. Settlement-subsistence models for this period are still being developed. Alan P. Sullivan (1986:330) has worked in the Upper Basin east of Desert View for many years, and his evolving model that the Cohonina were "semi-sedentary collectors" benefits from the best survey and excavation data set on the South Rim. Whether his ideas will carry the day will require additional work from diverse parties inside and outside of the GRCA. Even the better understood Pueblo II and Pueblo III periods in the Canyon have generated so many conflicting models (e.g., Effland et al. 1981; Euler and Green 1978; Schwartz 1966; Sullivan 1986; Sullivan et al. 2002) that Fairley best summed up the resulting picture as "perplexing" (2003:93).

On the Arizona Strip early pottery making is associated with the Virgin ceramic tradition, with common types including plain wares such as North Creek Gray and Shinarump Gray, and decorateds such as Washington Black-on-gray. As an example, assemblages with these types, and others, were associated with early Puebloan pithouses at the Jackson Flat Site and the Park Wash Site (Ahlstrom 2000), both excavated by HRA Inc. East of the Grand Canyon early ceramics are associated with the Kayenta ceramic tradition, typified by Lino Gray and Kana-a Black-on-white wares.

As elsewhere on the Colorado Plateau, the Puebloan occupation in the GGCR peaked during Late Pueblo II and came to an end by the beginning or middle of the A.D. 1200s. Probably the best-known and most visited Pueblo II/III sites in the Grand Canyon are Tusayan Ruin on the South Rim (Haury 1931) and the Unkar Delta settlement along the Colorado River (Schwartz et al. 1980; see also Schwartz 1991 for a popular account of the School of American Research investigations at this and other sites).

By A.D. 1000 or 1050, the region sustained an intrusion of Kayenta peoples from the east—the first generation that would call the interior of the Grand Canyon home. Cohonina and Kayenta ceramics often co-occur at sites from this period, but the nature of the interaction between these two groups is unknown. Between A.D. 1000 and 1100 ceramic assemblages are increasingly dominated by Tusayan White and Gray wares and Tsegi Orange Ware. Cohonina ceramics dwindle in numbers, proportionally, and essentially disappear by A.D. 1100 to 1150. Middle Pueblo II, between A.D. 1050 and 1100, witnessed a surge in habitation sites along the Colorado River in the eastern Grand Canyon. This period coincided with an influx of material and architectural traits strongly suggestive of the Kayenta region, such as kivas and rectilinear rooms. Patterned site layouts are common, with storage rooms, kivas, and middens (trash areas) often aligned in an east- to southeast-facing arc.

During the A.D. 1100s the number of sites and, likely, households, reached its maximum in the inner Grand Canyon, particularly in areas such as Nankoweap Canyon and the Furnace Flats stretch. The best-known sites from this period are the Pueblo II-II settlements at Unkar Delta along the Colorado River (Schwartz et al. 1980). Long-term habitations took advantage of the expanse of relatively flat land in these areas, which would have been necessary to raise crops to support the increased population. In addition to the typical suite of maize, beans, and squash, the RCAP excavations demonstrated that cotton was commonly grown during the Pueblo II-III interval, probably for use both as a food and for fibers. Sites of this era occur in canyon reaches boasting good cross-canyon travel routes, which would have facilitated seasonal movement of population, as well as interaction with groups to the north and southeast.

North and east of the Colorado River all major archaeological projects report Pueblo II (A.D. 900/1000-1150) sites—often in abundance at favored locations. Migration, rapid population expansion, or changes in subsistence strategies in response to climatic change are typically invoked to explain high site densities after A.D. 1050 (Effland et al. 1981; Euler et al. 1979; Westfall 1987:15), frequently at higher elevation settings such as the flanks of Mr. Trumbull and the North Rim of the Grand Canyon. Most would agree with Lipe and Thompson that "the time of the greatest Virgin Branch population was apparently between about A.D. 1000 and 1150" (1979:53).

A few examples will suffice. In a survey by the Western Archeological and Conservation Center (WACC) for lands adjacent to the Grand Canyon, the authors state that "the bulk of culturally identifiable sites dates from the…Pueblo II period" (Teague and McClellan 1978:179). This is also the case for WACC's survey of the Shivwits Plateau in 1990 (Wells 1991:Figure 5.2), where 54 of the 73 sites recorded (74.0%) had Pueblo II components. A recent WACC report by MacWilliams et al. concluded that, "Pueblo II remains dominate the collection, a fact that corresponds with the generally held tenet that this was the fluorescence of the Virgin Anasazi" (2006:111; see also Harry 2013).

Altschul and Fairley emphasize that the Virgin "expanded into every potentially arable location" (1989:130), occasionally constructing large C- or crescent-shaped pueblos with a dozen or more rooms. In fact, proximity to building material (Thompson 1970), arable land, and forested uplands appears to have a greater influence on site location than reliable water sources (Moffitt and Chang 1975). Teague and McClellan (1978:178) attributed this to a lack of dependence on agriculture, but the inhabitants may have taken advantage of salubrious conditions for upland dry farming and the re-charging of local springs.

The end of the Puebloan occupation of the Grand Canyon occurred earlier than in the so-called Kayenta heartland, where it persisted until nearly A.D. 1300 (Geib 2011; Lindsay 1969). Following conventional wisdom, Fairley (2003:95) judged that "by A.D. 1150 the majority of the Puebloan sites had been abandoned, and by A.D. 1200… the Puebloan occupation of the Grand Canyon had ended," although she cited Jones (1986:324) as suggesting use may have continued as late as A.D. 1220. The RCAP affirmed a late Puebloan presence that likely continued after the beginning of the 13th century. The dearth of reliable tree ring dates and the uncertain terminal date ranges of locally produced ceramics, however, make the date of the Puebloan exodus from the inner Canyon open to question. Few would argue that by A.D. 1250, the terraces and deltas of the eastern Grand Canyon were quiet.

Recognition of a continued Pueblo III presence on the eastern Arizona Strip has been increasing during the last 25 years. In the late 1970s, Moffitt and Chang stated that "the archaeological record of the Virgin sub-culture can no longer be traced after 1150" (1978:192); this is no longer the case (see Allison 2010; Buck 2004, 2005, 2006; MacWilliams et al. 2006). Perhaps the first hint of a Pueblo III occupation from an excavated habitation near the proposed GGCHNM was site "GC-671," reported in Thompson (1971a:24). Four radiocarbon dates from two pithouses had midpoints that ranged between A.D. 1140 and 1320. The A.D. 1320 date Thompson deemed "out of line," but he concluded that "at this and at other sites with 'late Pueblo II' manifestations, occupation lasted well beyond 1150…perhaps as late as 1225" (1971a:25). More recently, Westfall (1987:181) interpreted a series of radiocarbon dates from the Pinenut Site as evidence that "final abandonment" of the site was as late as A.D. 1275. This site is located near the Pinenut uranium mine, just west of Kanab Creek.

Protohistoric

After A.D. 1300, Native American cultural remains in the project area belong to two broad temporal subdivisions. The Protohistoric interval extends from A.D. 1300 to about A.D. 1500/1550, with the occurrence of the first Spanish entradas. The Historic interval extends from A.D. 1500/1550 to the modern era and includes the Mormon colonization of Utah and the initiation of U.S. Government exploratory expeditions across the southern Colorado Plateau. The pioneering exploration of the Southwest by the Spanish friars Dominguez and Escalante during 1776 (Bolton 1950), provides a convenient dividing point between early and late phases of the Historic. In fact, the friars may have crossed portions of the proposed GGCHNM as they worked their way east to find a suitable crossing of the Colorado River. As they traversed the Arizona Strip, they met and traded with Paiutes from the Shivwits and Uinkaret plateaus (Warner 1995).

On the north side of the Colorado River, the post-Puebloan inhabitants of the proposed monument are referred to as Southern Paiute because this was their recognized territory during the historic period (Kelley 1964). The chief temporal and cultural diagnostics of this period are Southern Paiute Brown Ware and Desert Side-notched projectile points. Southern Utes (Steward 1942) may have visited the area as well, and the separation of Numic-speaking Utes and Paiutes before the historic era is debatable (Pierson 1981:65). For that matter, other historically defined ethnic groups, such as the Navajo, Hopi, Hualapai, Havasupai, and Mohave made periodic use of lands and resources north of the river.

There is an unknown interval of time between the abandonment of the Arizona Strip by the Puebloans and the arrival of the southern Numic from the west and southwest. It may have been as little as a moment—if the cultures intermingled and overlapped in time and space (Gunnerson 1962; Simonis 2001), or the "newcomers" physically drove the Virgin out of their land (Ambler and Sutton 1986). Or, it may have been decades or centuries, if they arrived after A.D. 1300 (Euler 1974), and the Puebloan peoples had already withdrawn.

Regionally, there is a growing body of dates that may mark the beginnings of the Numic expansion. Along the Colorado River at the mouth of Whitmore Wash, a team of Grand Canyon National Park archaeologists dated a possible Paiute "midden" to about A.D. 1285 (Jones 1986). Another Paiute midden at Tuna Creek 90 miles upstream dated to about A.D. 1372. South of the proposed GGCHNM, the testing of roasting pits in Tuckup Canyon returned radiocarbon dates as early as the A.D. 1300s and 1400s (Huffman 1993), but were derived from aggregate samples of wood charcoal and subject to mixing of possible old wood.

Frederick Dellenbaugh made close observations of the Shivwits Paiute—whom he called the "Shinumos"—in the 1870s (Dellenbaugh n.d.). For the most part they kept to the north of the Colorado River, inhabiting the lower elevation canyons in the winter and the plateau uplands in the summer.

Kelley (1964) provided the most comprehensive summary of traditional Southern Paiute culture (see also Euler 1966). Unfortunately, her research was conducted in the 1930s, many decades after the abandonment of traditional Paiute lifeways. From Kelley we know that the Southern Paiute practiced a subsistence strategy based on seasonal transhumance, supplemented by small patches of corn and squash that were casually cultivated by some band members. Bye (1972) goes into some detail on the range of plants and foodstuffs that the Paiute consumed, partially based on collections gathered by Powell and Palmer.

In the Grand Canyon-Parashant National Monument, most major projects have reported sites or components that were suspected to post-date A.D. 1300. In terms of ceramics, one of the more productive efforts was Shutler's work on the Shivwits Plateau and the adjoining "Grand Canyon terrace," located to the west of the proposed GGCHNM. Speaking of the project as a whole, which included the Virgin and Muddy river area, he said, "Southern Paiute Brown Ware sherds were noted at almost all of the pueblo sites of the area" (Shutler 1961:69). On the Shivwits and Grand Canyon terrace, Paiute sherds were sometimes recorded in such abundance that they outnumbered Puebloan sherds on the same site (Shutler 1961:Tables 3-5).

On the South Rim of the Grand Canyon, west of the proposed GGCHNM, are the Yuman-speaking Hualapai and Havasupai nations. Henry Dobyns and Robert C. Euler (1960, 1967, 1970, 1971, 1976; see also Dobyns 1974a, 1974b), who was later archaeologist for Grand Canyon National Park, co-authored several formative volumes on the Pai Indians of Northern Arizona. Douglas Schwartz furthered research in the 1950s (1955, 1956, 1959), and would later conduct extensive archaeological excavations at Unkar Delta and elsewhere in the inner Grand Canyon. Other classic references include Cushing (1882) and Spier (1928).

The focus here is on the early tribal territory of the Havasupai, as it encompassed all lands proposed for the GGCHNM south of the Colorado River (Schwartz 1983:13). The historic territory of the Havasupai extended from the river to Bill Williams Mountain to the south, and from the Aubrey Cliffs east to the confluence of the Little Colorado River and the Colorado River. Euler (1961) lists numerous instances of historical maps and documents placing the ancestral Havasupai west of the "Moqui," or Hopi villages, with no intervening tribes. Forbearers of the Havasupai may have encountered Spanish explorers as early as the mid-1500s, but they were first mentioned by name (as the "Coninas") about a hundred years later (Hackett 1937:264). The seasonal round of the Havasupai consisted of summer agriculture in the Grand Canyon and southern tributaries, such as Cataract Canyon, and dispersal to the wooded rim and plateau country in the winter.

For years there was a debate between Euler and Schwartz concerning the origin of the "Coninas," with the latter taking the stance that the Grand Canyon Pai had evolved from the archaeological tradition called the Cohonina (see Euler 1958 for an alternative view). Identifying Pai or proto-Pai cultural remains in the vicinity of the proposed GGCHNM can be difficult, as the self-proclaimed "People of the Blue-Green Water" constructed lodge-pole earthen homes and were expert makers of basketry—material remains that did not readily survive in open contexts. It can be reasonably assumed that certain remains located south of the Colorado River that date to the Protohistoric or Historic periods are Pai; the extensive roasting and habitation features at Granite Park in the western Grand Canyon are one example. One recognizable manifestation of Pai use in close proximity to the proposed GGCHNM is an archaeological site along the Bright Angel Trail with almost 300 pictographs associated with the Archaic, Cohonina, and Havasupai peoples (Collette et al. 2009:28). In a recent archaeological survey of the Indian Garden area, below the South Rim, constructed walls were found that overlook the Bright Angel Trail (one of which was situated atop a nearly-inaccessible rock pinnacle). There are ethnographic accounts of the Pai stationing "lookouts" in the Indian Garden area, and these features have the appearance of vantage points along this well-known route (see Collette 2011). Pai families seasonally inhabited Indian Garden until the late 1880s, when they were displaced by development of the area as a mining and tourist destination (Hirst 1976).

From an archaeological perspective, some of the most provocative historic cultural remains are sites related to the subjugation of the Navajo by the U.S. Army and their internment at Fort Sumner between 1864-1868. Although the forbidding landscape of "Bosque Redondo," as Fort Sumner was also known, seems far removed from the beauty of the Canyon, it was within the maze of tributaries and uplands of the eastern Grand Canyon where many Diné fled from Christopher "Kit" Carson, the commander of the Navajo campaign. As many as 1,000-2,000 Navajo escaped to the wild confines of Navajo Mountain (Roessel 1983), and an unknown number retreated to the eastern flanks of the Colorado River, some finding safety by crossing the Colorado and San Juan rivers. Abandoned hogans and camps of the offspring of these refugees dot the open landscape between the Canyon and Hamblin Wash, and Gray Mountain, between the current community of Cameron and the GRCA, was also a known sanctuary. Van Valkenburgh relates how groups of Navajos used the Tanner Trail to access the inner Canyon, while others drove their sheep up what is now the Bright Angel Trail, "where they had to hoist their sheep up over steep places with yucca fiber ropes" (1941:68). Later, Gray Mountain was often used as a summer camp for raising sheep, and Navajo artist Hoke Denetsosie had fond memories of growing up there in the 1920s, and of his grandfather, Diné Ts'osi, who "climbed down with ropes into the Little Colorado River and packed drinking water back up" (Navajo Community College Press 1977:73).

Even before the military operations related to Fort Sumner, Navajos would forage for pinyon nuts along the South Rim "as far west as El Tovar" (Van Valkenburgh 1941:68). Even though this was considered to be Havasupai territory, the two tribes were "usually friendly." Farther up the Colorado River, roving Navajo bands would cross at the old Crossing of the Fathers to hunt on the North Rim in "Shavowitz Piute" territory. Likely Navajo sites have been found along the banks of the Colorado River during recent archaeological surveys (Spurr and Collette 2007:95).

Both the Hopi and Zuni have origin stories that derive from sacred locations within the Grand Canyon, which plays an important part in the ethos of each tribe. Ancestral Puebloan sites can be found throughout the Canyon, but are particularly prevalent in the eastern reaches (east of Bright Angel Creek; see Fairley et al. 1994). Data recovery work by RCAP at nine river-level sites in the Grand Canyon showed that, by the late 1000s, inhabitants began constructing pueblos with site layouts and ceramic traditions very similar to cultural remains from the heartland Kayenta region to the east (Neff et al. 2016). Clearly, peoples with ancestral ties to today's Hopi and Zuni were moving into the Grand Canyon and making it their home.

By the late 1200s, Puebloan peoples had mostly abandoned the inner Grand Canyon to congregate at large villages to the east, including the formative expressions of the Hopi Villages of today. And yet, the Grand Canyon was not empty of life during this time. In addition to Pai/Paiute sites, archaeologists find occasional sherds of Jeddito and Awatovi Yellow Ware—Pueblo IV Hopi ceramics that date after A.D. 1300. The occurrence of yellow ware is usually attributed to Hopi visitors on pilgrimages of trading expeditions (e.g., Adams et al. 1961; Sharrock et al. 1963), but the vessels might also have been carried into the area by Numic "middlemen," as documented historically (Bolton 1950).

The Hopi and Zuni continued to visit the Grand Canyon and leave traces of their visits, even as intruders from the south began to make inroads into their homelands. Cárdenas, the Spanish explorer who was guided to the Grand Canyon by members of the Hopi tribe, mentioned the general aridity of the South Rim (Udall 1987:109), and reported that the Hopi, when crossing through the area (sometimes to visit the Havasupai), would cache gourds of water along the rim. For Cardenas, it was a short anecdote concerning a profitless trip, but to the Hopi—and their Pai, Paiute, and Navajo neighbors—the meeting foretold centuries of change for the peoples of the Grand Canyon.

Concurrent with the exploration of the Arizona Strip by Dominguez and Escalante, missionary Francisco Garcés visited Indians around Kingman and Peach Springs that he identified as "Jaguallapais" (Dobyns and Euler 1976; McGuire 1983). The Pai nations to the south of the Colorado River may, at first, have appeared to be immune to the effects of Spanish colonialism in the American Southwest. Indirectly, however, the introduction of Spanish material goods and diseases, such as smallpox and influenza, "transformed Pai culture before the first American trappers and explorers entered Pai homelands" (Shepherd 2010:26).

Beginning with Capt. Lorenzo Sitgreaves' expedition into Hualapai territory in 1851, the floodgates of Euro-American expansion were opened. Said historian Jeffrey Shepherd:

> *Sitgreaves entered Pai lands to determine their amenability to a possible railroad, and his guide received a welcome befitting the party's objectives. Men from either the Cerbat Mountain or Hualapai Mountain band shot the guide. Other military explorers, such as Francois Xavier Aubrey in 1853 and Lt. Amiel W. Whipple in 1854, elicited similar reactions* (Shepherd 2010:29).

Armed conflict followed the intrusion of these and other expeditions in the 1850s, culminating in the establishment of a wagon route through Pai lands by Lt. Edward F. Beale in 1857-1858. As settlers used the road to move west, the Pai began a constant campaign of harassment, ushering in a military presence that was symbolized by the construction of two new forts: Fort Mohave on the Colorado River in 1859, and—after a brief interlude during the height of the Civil War—Fort Whipple near Prescott in 1863.

The steady advancement of settlers, gold miners, and U.S. troops in northwestern Arizona kept the pressure on the Pai people. Soon, Anglos were not just passing through, but settling on prime Pai land. When a respected leader, Wauba Yuma, was killed by Anglos, large-scale battles followed and by the mid to late 1860s "a full-blown racial war had begun in northwestern Arizona" (Shepherd 2010:34). Starting in 1867, many of the attacks were spearheaded by Col. William Redwood Price, who took a page from Kit Carson's Navajo campaign to implement something of a scorched earth policy against the Pai. The southern and central bands of the Hualapai took the brunt of the warfare, while northern bands—such as the "Havasooa Pa'a" near the Grand Canyon—were spared the worst of the violence.

By 1870 the most rebellious of the Hualapai leaders had been killed or had surrendered and—not unlike the Navajos forced encampment at Fort Sumner—the Hualapai peoples were forced onto the sweltering lowlands of La Paz along the lower Colorado River. A reservation was established in 1883, but it was generally unproductive and supported only a dozen families in 1905.

Garcés was also guided to the Havasupai's domain in Cataract Canyon but Spanish influence was considered to be "negligible" (Schwartz 1983:15). In the decade following Sitgreave's initial visit, the Havasupai suffered from many of the same degradations as their Hualapai neighbors, with the added impact that miners were actively prospecting Cataract Canyon for copper (Hirst 2006). A small reservation was created within the canyon in 1880, effectively cutting the Havasupai off from their winter foraging grounds on the plateau. Much later, in the 1970s, the tribe reacquired lands in the surrounding uplands and within Grand Canyon itself.

The Southern Paiute bore the brunt of slave-raiding Spanish colonialists as early as the late 1700s (Brugge 1968), although in 1776 the Spanish priests Dominguez and Escalante "noted little evidence of any foreign presence among them" (Kelly and Fowler 1986:386). This soon changed and, until the Mormon colonization efforts in Utah, Paiute slaves were routinely captured and sold by Ute, Navajo, Spanish, and American raiders, leading to population depletion, disease, and displacement from their ancestral lands. Like the Pai, some Paiutes of Southern Utah retaliated with small-scale raids, but Mormon missionary Jacob Hamblin has been credited with acting as a level-headed intermediary during this period, working to head off major conflicts (Euler 1966). By the late 1860s plans were afoot to locate the tribe to reservations, such as the Moapa and Shivwits reservations, and the tribe lost access to the majority of their ancestral land base. After decades of federal neglect, the Southern Paiute tribe succeeded in the 1970s and 1980s with regaining federal trust status (lost in 1957) and increasing land holdings.

Fur trappers and explorers became more common in the 1830s, many reaching the Virgin River by way of the Sevier, and then moving south to the homeland of the Mohave Indians. In 1830, Yount and Wolfskiller were the first to traverse the longer route of the Old Spanish Trail, describing both "Piuch" and "Mahauvies," and lumping them with other "savage hords [sic] of the west" (Camp and Yount 1923:38-39). The accounts, while ethnocentric, remain valuable, as they show that the native population of the region "was still essentially aboriginal" (Euler 1966:43), and not yet overrun by Anglo influence.

Accounts increasingly mentioned the impact of slave raiding on the local tribes, and between 1848 and 1849 traffic along the Old Spanish Trail grew with the arrival of various companies and "gold seekers." An extensive journal by Orville C. Pratt of his journey along the trail suggests that the Paiutes were present in large numbers, farming in some areas, and generally peaceful. This and other journals extracted in Hafen and Hafen (1954) show that 1849, in particular, was a busy year along the Old Spanish Trail for packers and wagon trains of emigrants, and may have been a tipping point in the ability of local tribes to sustain their traditional lifestyle.

The true test came in 1850, however, when Mormon settlers based out of Salt Lake Valley set out for Southern Utah and established Cedar City the following year. The journey was the first time that the intent of the travelers was not to "pass through," en route to California, New Mexico, or elsewhere, but to put down roots and make a home. Settlements soon multiplied and by 1853-54 the first Mormon "Mission to the Indians" of Southern Utah was underway with Jacob Hamblin in charge. Although the Mormons opposed slave traffic, which was "firmly established" by the time they arrived in Utah (Brooks 1944a:6), Brigham Young did encourage his followers to adopt—by way of purchase, if need be—Indian children. As the Mormons worked their way south, conflict inevitably followed, but it is the opinion of Euler that "the range of the Southern Paiutes remained fairly stable in the 1850's" (1966:70). During an 1859 mission, also led by Jacob Hamblin, Paiutes were intermittently seen across the Arizona Strip and as far as the Shonto Plateau in Northern Arizona (Brooks 1944b).

To the west of the proposed GGCHNM along the west bank of the Colorado River, Paiutes referred to as the Chemehuevi were often described by various exploring parties, such as those led by Lt. Amiel W. Whipple (1854) and Lt. Joseph C. Ives (1857-1858). Later, in 1871, Lt. George M. Wheeler met Paiutes near "Pierce Ferry" and the mouth of Diamond Creek (Wheeler 1872, 1889). One of his officers, Lt. D.A. Lyle, reported that the "Se-Vitches"—or, Shivwits Paiute—on the Arizona Strip, had "little communication with whites" (Lyle in Wheeler 1872). In the area immediately north and south of the Grand Canyon, contact tended to be less formal, with small parties of Pai and Paiutes engaging with settlers, miners, trappers, and ranchers.

West and north of the proposed monument, settlements such as Kanab and Pipe Springs were established in the 1860s, with the former the target of a marauding band of what Euler (1966:80) deemed probable Navajos, who escaped with captured livestock. By 1871 interactions between Navajos and Kanab townsfolk were more amiable as John D. Lee observed that the community was "full of NavaJoes in to trade" (Cleland and Brooks 1955:173). It is also clear, from accounts by Frederick Dellenbaugh and others, that Navajos could routinely be observed crossing at Lee's Ferry and on the trail to Kanab during this interval.

About the same time, E.O. Beaman, a photographer on John Wesley Powell's second expedition down the Colorado River, helped two "Moquis" from Oraibi make the crossing at Lee's Ferry (what Beaman simply called "the Paria") in an old boat. The Hopi gentlemen were also on their way to Kanab with "skins and blankets," and Beaman opined that, "They were, so far as I could learn, the first of the Moquis that had ventured to the northwest bank of the Colorado on a trading expedition" (Beaman 1874:624). Beaman based his claim on a "tradition among the Utes" that the Hopi had long ago made a pact with their northern adversaries to stay on the south side of the river if the Utes kept to the north of it. "The Moquis are said to have held strictly to the agreement," said Beaman, "but the Utes, less steadfast, have entrenched upon the Moquis territory in large bands for years."

Until 1869 the formidable chasm of the Grand Canyon was a barrier to most Euro-American explorations, although neighboring tribes crossed and re-crossed the Colorado River for both peaceful trading and less pacific raiding. In that year Major Powell led his first trip down the Colorado through the Grand Canyon, and followed it with an extensive trip in 1870 into the heart of Paiute territory that bordered the North Rim of the Canyon. Powell is perhaps best known as an intrepid explorer, but he was also a born ethnographer, and took detailed notes concerning the "Uinkaret" Paiutes in the Mount Trumbull area and elsewhere (Powell 1961, 1981), both on this and subsequent trips in 1871 (the date of his second journey down the Colorado) and 1872.

By the early 1870s a different portrait of the Paiutes was beginning to appear in the journals and accounts of Powell and his men, which Euler summarized as "economic disorganization resulting from transculturation" (1966:84). In stark, but sympathetic, terms Powell commented, "The Pah-Utes prowl about, begging…half starved" and presenting "a pitiful, abject appearance" By 1872 there is some indication that the Paiutes may have begun to abandon the Kaibab Plateau (Gregory 1948-49), but others were still observed at Kwagunt Canyon in Grand Canyon and Mount Trumbull (Dellenbaugh 1909; Gregory 1948-49). E.O. Beaman remarked that the land southeast of Lee's Ferry was still country occupied by a "renegade" band of Pah-Utes (1874). Both Paiutes and Navajos have historically occupied lands beneath the Echo Cliffs, between what is now Bitter Springs and The Gap. When Beaman's party reached the banks of Moenkopi Wash they found themselves "in the midst of a Navajo camp, surrounded by cornfields" (Beaman 1874:625). His comment suggests that by the early 1870s the Diné had pushed well past the Hopi villages and closer to the Colorado River.

Powell was sympathetic to the plight of the Paiutes and other Indians in the vicinity of the Grand Canyon, but by the mid-1870s acknowledged that "their hunting grounds have been spoiled, their favorite valleys are occupied by white men, and they are compelled to scatter in small bands in order to obtain subsistence" (Powell and Ingalls 1874:41-42). The only reasonable recourse, he felt, was to compel the natives to reservation life, which might afford them a land base where they could make a living, unmolested by white men. Small reservations and ad hoc encampments were established in the late 1800s, and "by the first decade of the twentieth century…any semblance of native Paiute life was a thing of the past" (Euler 1966:96).

The gradual contraction of the Southern Paiute nation was directly related to the rise of Mormon settlement and use of the Arizona Strip, beginning in the late 1850s. Some accounts have Jacob Hamblin building crude structures at Kanab in 1858, with settlers arriving a year later (Bradley 1999:60-61); cattle raising in the area was underway by at least 1863. William B. Maxwell, who traversed the eastern Strip in 1847 (and may have been the first Mormon to do so), claimed Moccasin Spring (aka "Sand Spring"), located a few miles north of Pipe Spring, by 1860. A 160-acre ranch was established at Pipe Springs itself in 1863 by James M. Whitmore. Two years later Whitmore and his brother-in-law were killed while looking for stolen cattle—ostensibly by the Paiute, although the latter blamed Navajo "marauders" (Larsen 1998:101-103). Mormon militiamen killed a number of Paiute in retaliation, although there is good evidence that Navajos raiders were responsible for much of the depredation on the Arizona Strip during the 1860s.

CHAPTER 6

HISTORY OF EXPLORATION AND SETTLEMENT BY ANGLO-EUROPEANS

MOLLY JOYCE AND LARRY STEVENS

Introduction

Dramatic changes began to occur in the proposed GGCHNM region following the arrival of Europeans. Captain Lopez de Cardeñas first set eyes on the landscapes of the Mesa lands and Grand Canyon in 1540, guided to the rim by members of the Hopi tribe (Udall 1987). Typical of early Spanish exploration, the geological formation of the Grand Canyon and its small groups of indigenous cultures were of little interest to explorers like Cardeñas and Francisco Vazquez de Coronado. The purpose behind their exploration of the northern territories of New Spain was to discover the Seven Cities of Cibola. Thus, the remarkable chasm and its desolate surroundings were no more than a footnote in their journals. For the next 236 years, the region continued on in obscurity until Silvestre Vélez de Escalante and Francisco Atanasio Domínguez crossed the Kaibab Plateau searching for a water route to the Spanish Missions of Monterey, California. From this point, recognition of the region evolved relatively quickly. This chapter summarizes the 500 years of European exploration and settlement in the proposed Greater Grand Canyon Heritage National Monument – a history that is intimately tied to that of the Grand Canyon. Here we highlight the evolution of perspectives held by the men and women, explorers, scientists, artists, politicians, and settlers that transformed the region from an obscure southwestern landscape to one of the most culturally defining monuments on Earth.

Between 1500 and 1775 the Grand Canyon and the Kaibab Plateau remained virtually untouched and was avoided by early Spanish explorers and Anglo settlers, largely due to political objectives and cultural predispositions of the Spanish crown in the 16th-18th centuries. Spain rejected secularization and disapproved of scientific ideas that spread across Europe during the Age of Enlightenment (Pyne 1998). During the 16th-18th centuries, Spain retained its orthodoxy and acted as the epicenter of the Counter-Reformation, despite accelerated exploration of the New World and intensifying scientific curiosity amongst other European nations. Despite Spain's capacity for naval exploration, its capacity to absorb discoveries within the context of natural history was constrained by religious conservatism. Thus, the first Europeans to set eyes upon the geological wonder were also among those most ill-equipped to appreciate its significance. Focusing exploration on the discovery of Central and South American civilizations, Spanish explorers such as Captain Lopez de Cardeñas, Silvestre Vélez de Escalante, and Francisco Atanasio Domínguez placed little role in the Grand Canyon region, recording the giant gorge as an obstacle to be avoided and circumnavigated.

Because of this, it took almost 400 years of exploration and geopolitical contests to transform the region of the GGCHNM into its present state. Transferred from the hands of Spain to Mexico, and finally to the United States,with strong influences of Native Americans, Mormons, and the U.S. government, it now represents a complex cultural landscape. Investigating this history reveals that complexity and multidimensional historical significance. From a geological obstacle to imperialist Spanish explorers, to a federally protected Wonder of the World, the region has played an enormous role in the lives and cultures it now supports.

Early Spanish Explorers

The story of how the Spanish conquistadors reached the Grand Canyon began 12 years before they set eyes on it. In 1528, Pánfilo de Narváez set out on an expedition to explore northern New Spain (present day Chihuahua, New Mexico, and Arizona), determined to surpass the infamy of his competitor, Hernan Cortés. Narváez left Cuba with 300 Spanish soldiers and 500 horses to claim new land for the Spanish crown. Hurricanes in the Gulf of Mexico shipwrecked the expedition in Florida, and survivors were attacked and hunted by Alabaman and other southeastern Indian tribes. The expedition barely made it on foot to Galveston Island, and only four of the original 300 survived. One of these men was Álvar Núñez Cabeza de Vaca, who became the first European to explore the American Southwest. The one with the most dramatized tales of survival, Cabeza de Vaca trekked across Texas, making first contact with Southern Plains tribes. By 1536, he had walked from Galveston Island, across south Texas encountering Karankawa, Tonkawa, and other Southern Plains tribes, as well as Zuni, and other Puebloan cultures. His journey took him across southern New Mexico and Arizona to Baja California, and down the west coast to Culiacan. Upon reaching Mexico City, Cabeza de Vaca recorded and published an account of his journey, the first ethnographic documentation of North American Indians. This report inspired several Spanish expeditions including that lead by Francisco Vazquez de Coronado and his search for the Seven Golden Cities of Cibola. Without Cabeza de Vaca's account, exploration to the northern deserts of New Spain would have been delayed by decades or centuries.

On February 23, 1540, Coronado set out from Compostela, the capital of Nueva Galicia, with 300 Spaniards and 1,000 Indians. Amongst his party was Captain Garcia Lopez de Cardeñas. The expedition had reached Cibola in August of 1540 and conquered the Pueblo city of Hawikuh, the first city captured by the expedition (Winship 1904). From Hawikuh, Cardeñas and a small group of soldiers detached from the main expedition to explore regions to the northwest. Members of the Hopi tribe led the men through the Mesa lands of northeastern Arizona, bringing them through the southern GGCHNM region to the South Rim of Grand Canyon.

As the first Europeans to see the Cañon del Colorado, Cardeñas made little note of the Canyon in his journal. He and his party greatly underestimated the depth of the Canyon, believing the monolithic formations to be "boulders," and the Colorado River to measure a mere 2 m wide (Winship 1904). For three days the party looked for paths to descend to the river for water. Unsuccessful, he assigned three of his men to scout a trail. After many hours, the men returned, unable reach the river. They informed Cardeñas that the Colorado was a great deal larger than they had estimated. They also informed him that the "boulders" Cardeñas observed from above were in fact taller than the Great Tower of Seville, the tallest building in the world in 1540, standing at nearly 90 m tall. The Hopi guides that led the party to the Rim of the Canyon possibly knew of ways to reach the River, but it is likely that they refrained from showing Cardeñas these routes. Seen by Cardeñas as an obstacle, he and his party returned to Coronado 80 days later and continued their trek to the northeast (Winship 1904). A total of 236 years passed until Europeans revisited the region.

The Escalante-Domínguez Expedition

As the Continental Congress of America declared its independence from England and Captain James Cook launched his third voyage to explore the Pacific Ocean, Juan Bautista de Anza was establishing missions and presidios along the coast of California, and the interior of northern New Spain remained unexplored. Silvestre Vélez de Escalante and Francisco Atanasio Domínguez, both Franciscan priests, launched an expedition to establish an overland trail connecting the inland settlement of Santa Fe with the Spanish presidio of Monterey, California.

The Domínguez-Escalante expedition set out from Santa Fe taking a northern route through Colorado, trekking across northern Utah and along the Great Basin. Harsh winter storms forced the expedition to return southeastward to Santa Fe, circumnavigating the mountains of southwest Colorado. By October 22, 1776, the expedition crossed the Kaibab Plateau, traveling from west to east (Fig. 6.1). They entered the valley where Marble Canyon Trading Post and Lodge are located today, coming up into the valley between the Echo and Vermilion Cliffs (Warner 1995). The expedition was running low on provisions, horses were dying, and the terrain slowed their progress. After crossing the eastern edges of the plain, the expedition descended "a very high ridge, steep and full of rubble," making camp beneath a "high cliff of gray (tawny?) rock, naming the spot San Benito de Salsipuedes," ("San Benito, get out if you can"; Warner 1995). The tall gray cliffs were the Chinle Shale near present day Lees Ferry. In this part of the Grand Canyon, they encountered camps of Indians, whom Escalante called Sabuaganas (Uinkaret Paiute), and with whom they shared Catholic doctrine (Warner 1995). Based on their journals, the Sabaguanas were not responsive to their teachings.

By November 1776 they reached the Hopi village of Oraibi, one of the oldest human settlements in North America, and is located on Third Mesa in Northeastern Arizona. Leaving Arizona, they returned to Santa Fe by January 3, 1777, having never made it to Monterey (Warner 132). The Spanish expeditions of Escalante-Domínguez and Cardeñas revealed the limited level of importance that Spain placed on northerly exploration. Of all expeditions throughout the Southwest, only two expeditions mentioned Grand Canyon, although those brief forays have become some of the most cited parts of their explorations (Pyne 1998).

Fur Trappers

The absence of attention paid to the region was due, in part, to Spain's international policies during the 18th century. New Spain stretched from the Yucatan to the northern borders of Utah, and Nevada, and from the Mississippi River to the Pacific. As the United States, England and France encroached, the borders slowly shifted, and by the beginning of the 19th century, Spain actively blocked further intrusion by the United States; consequently, few Anglo-Americans crossed the land now proposed as the GGCHNM after 1776. After the Mexican Revolution in 1821, the interior of western North America suddenly opened to the United States Fur trappers rushed into the American Rockies and were among the first to observe and record the American West (Fig. 6.2). James Ohio Pattie, a trapper from Taos, New Mexico, documented his journeys through the GGCHNM and Grand Canyon region in his *Personal Narrative*, one of several trapper accounts that glorified the American West and its wilderness (Pattie 2006).

Fig. 6.1 Historical Marker dedicated to the Escalante-Domínguez expedition that passed through Houserock Valley, south of Vermillion Cliffs in 1776. Photo by Molly Joyce.

In his vague accounts, Pattie described the area surrounding the Canyon as desolate and prison-like (Pyne 1998). He was amongst the few trappers to even note the Canyon in his memoirs. The Canyon's immense scale forced trappers to avoid it, taking routes farther north along the northern Kaibab Plateau and along the Old Spanish Trail

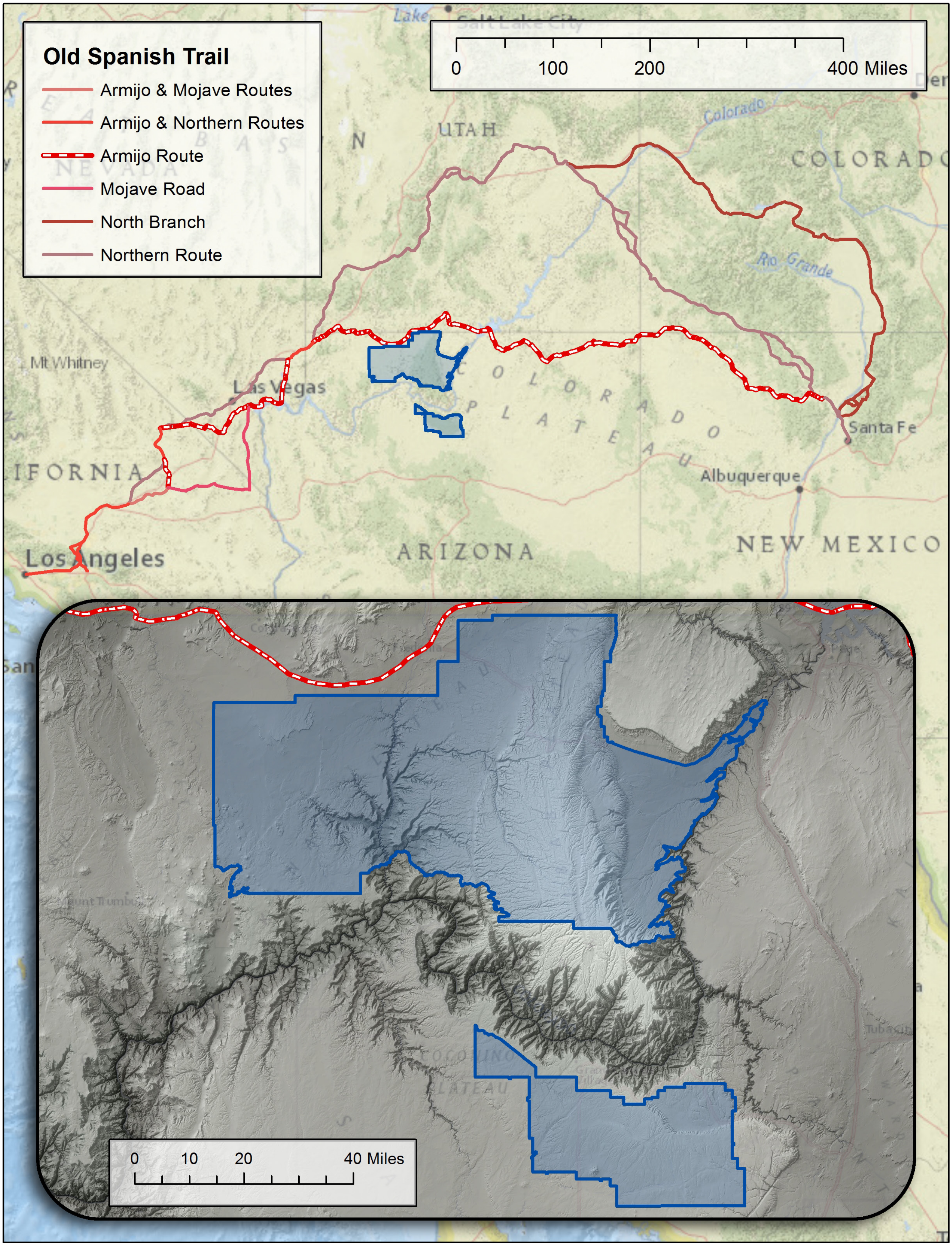


Fig. 6.2 Map depicting the Old Spanish Trail, the official trail established by Escalante and Domínguez. The Armijo Route passes along the northern border of the proposed GGCHNM, and the Escalante-Domínguez journal of their expedition describes visiting areas near Marble Canyon and the Vermillion Cliffs. Map produced by Jeff Jenness.

(derived from the Domínguez-Escalante expedition, Fig. 6.2) - a region more plentiful in game. As a result, fur-trapper memoirs recorded their stories in the region that lies within the GGCHNM, lending to the significance of this geographical area. As the 1800s continued, new forces at work in the eastern United States would bring more white settlers to the plateaus overlooking Grand Canyon, continuing to shape the regions historical prominence.

American Exploration and Mormon Settlement

Throughout the 1840s, the Old Spanish Trail (Fig. 6.2) was a frequently used corridor by fur trappers and explorers, and prospectors who were drawn west to California - growing the Canyon's reputation in recorded history. Following Mexican Independence, and despite passage by trappers and gold miners, it remained an enigma to the world's imagination until 1848. Along with the California gold rush (1849), one of the most significant political events to affect settlement in the American West included the Treaty of Guadalupe Hidalgo. Following the end of the U.S. Mexico War in 1848, the Treaty placed the Canyon and its surrounding country in the middle of a vast new territory belonging to the United States. No longer a remote desert of northern Mexico, 1.36 million km^2 now fell under U.S. jurisdiction, opening it to people seeking new opportunities west of the Mississippi River.

Facing religious persecution in Illinois and Missouri, Mormon frontiersman left their homes in Illinois and began exploring the unsettled region south of Salt Lake City in 1847. From the Wasatch Front to the deserts of the eastern Sierras they sought sites that would sustain settlements for the state of Deseret (the proposed but never recognized state of the Church of Jesus Christ of Latter-day Saints). Colonization of Deseret was successful, particularly across Utah, but the southwestern Colorado Plateau remained less populated than the areas surrounding Salt Lake City. Indigenous tribes, such as Navajo and Paiute, resisted the advancing settlement of Mormon colonists. Relations between the groups grew hostile, developing into violence. Nonetheless, pioneering families and frontiersman established themselves on the Plateau.

As members of the church pushed beyond the settlements of St. George and Cedar City (established in the 1850s) they came into contact more frequently with "Lamanites" - their term for American Indians (Rusho 1981). As a result of the conflicts, Brigham Young encouraged settlers to share the Mormon doctrine with these tribes (Rusho 1981). Upon settling in a new region, missionaries made it their work to evangelize to Paiute, Ute, and Hopi. Generally, their teachings were ignored, as many of these groups had already rejected the teachings of Catholic missionaries more than 70 years before. It was not until the Utah War that relations between Mormons and tribes became more amicable.

Brigham Young ordered Jacob Hamblin, perhaps the most famous and recognized of the Mormon frontiersman, to establish peace treaties with Navajo and Hopi in an effort to rebolster relations and missionary efforts, and lead the Southern Paiute mission in Santa Clara, near modern day St. George. Also known as the "Buckskin Apostle," Hamblin was able to successfully established alliances with many of the tribes along the Colorado. However, many groups refused his efforts, including the Hopi. On his return to the northern reaches of the Plateau, he and his men crossed the Colorado River at the mouth of the Paria river in 1864 (present day Lees Ferry). Further attempts to evangelize to tribes in the region resulted in violent encounters, including one between Hamblin's party and a group of Navajo in 1865. With tensions also growing between the Deseret and the Untied States, Young encouraged Mormon settlers to abandon the region.

As the Utah War progressed, Young encouraged Hamblin to convince native groups to support the Mormon side. Hamblin made attempts to discourage Navajo bands from raiding Mormon settlements in southern Utah, but he was unable to find any Navajo groups due to hostile relations between the Navajo and the U.S. Army. The United States Army Corps of Topographical Engineers was ordered to survey newly acquired U.S. territories.

Multiple expeditions navigated the GGCHNM region throughout the 1850s, in part to identify a route for the transcontinental railroad, but also to establish supply routes for U.S. troops in the intensifying Utah War (also known as the Mormon War). The Ives Expedition, 1857 to 1858, was sent by the War Department. Led by Lt. Joseph Christmas Ives, they explored the Colorado River. Starting up the mouth of the Colorado River in an iron-sided steamboat called "The Explorer," the expedition explored upriver up near present day Hoover Dam. There the steamboat struck a rock and was incapacitated (Hughes 1978). Abandoning "The Explorer," the expedition trekked overland across Arizona, south of the Grand Canyon. The expedition produced early maps of the Grand Canyon, and now-famous depictions of the region drawn by F.W. Egloffstein.

On September 11, 1857, a party of Arkansas emigrants known as the Baker-Fletcher party left Salt Lake City and, at the suggestion of Hamblin, continued along the wagon trail to Mountain Meadows (in southwestern Utah). A Mormon militia led by John D. Lee (a Mormon leader from Illinois) split the party up and then killed the men, women and children. The event became known as the Mountain Meadows Massacre. Lee attempted to divert blame to Paiute Indians, but rumors circulated confirming Lee's involvement. Fir his crimes, Brigham Young excommunicated Lee from the Mormon Church and sent him to establish a river crossing along the Colorado River. Lee founded the crossing at present day Lees Ferry, along with a ranch known as Lonely Dell Ranch. Following court orders in 1874, Lee was arrested, convicted in 1876, and executed by military shooting in 1877. Emma, Lee's 17th of 19 wives, took over the ferry's operations until the Mormon Church bought it from her in 1879 and granted the rights to Warren Johnson.

With tense relations between Mormons, Navajo and other indigenous tribes, as well as the U.S. Army, Hamblin and his men kept watch over plateaus and valleys south of their settlements in St. George. When the Ives Expedition embarked, their presence on the river was not overlooked by Hamblin. He and a small group of men went to investigate the expedition and its motives. They encountered Ives and his men in 1858, before Ives crashed the Explorer. Nothing came of their encounter, despite Hamblin's suspicions of Lt. Ives' purpose for exploring the Colorado River. Hamblin continued monitoring the region and worked to improve relations with tribes, even after the Utah War ended.

The Havasupai, whose historical territory included the banks of the Colorado River in the summer and the plateaus of the South Rim in the winter, were granted their reservation in 1882. It now lies on the southern boundary of present-day Grand Canyon National Park, southwest of Grand Canyon Village, and west of the proposed boundary of GGCHNM. As a tribe with direct ties to Grand Canyon and its surrounding landscape, the Havasupai befriended some early white settlers like Hance and William Wallace Bass, showing them places of interest within

Fig. 6.3 North of the Grand Canyon's North Rim, the East Kaibab monocline is exposed, due west of Marble Canyon and Lees Ferry. Photo by Kristen M. Caldon.

the Canyon. Bass, who had moved to Williams in the early 1880s, first saw the South Rim in 1884. He built a homestead and established copper and asbestos mining claims in the Canyon. Like Hance, Bass realized the business opportunities in tourism Canyon and he converted to guiding tourists through the Canyon (Hughes 1978). Hance established the first trail to the North Rim of the Canyon, and often took visitors to see Supai village. He built a 60-mile stagecoach road from Williams, AZ to the South Rim and his homestead-turned-hotel became a destination for tourists, artists, geographers, and geologists, among others. The Fred Harvey Company and the Santa Fe Railroad eventually bought Bass out in 1923, around the same time that Harold and Nina Bowman founded Jacob Lake Inn on the North Rim.

The Grand Canyon and its surrounding plateaus became more heavily visited after ambitious businessmen, such as Fred Harvey and investors of the Atchison, Topeka, and Santa Fe Railroad followed the lead of Hance and Bass and capitalized on the tourism industry that now defines the region. The Fred Harvey Company, with the help of Bucky O'Neill and eastern investors, developed the rail line to the South Rim in 1901 and built lodging there (Hughes 1978). Rumors, stories, and paintings of the Colorado Plateau's unsurpassed beauty reached the East Coast and tourists included artists and natural scientists, as well as heads of state, such as Theodore Roosevelt.

Theodore Roosevelt

Until the turn of the 20th century, the Grand Canyon region largely passed unnoticed by Spanish, Mormon, and American explorers, and had been avoided by trappers and frontiersman. It was the last of America's great landscapes to be mapped and still remains incompletely explored. However, it was among the first of America's landscapes to be formally protected. With Theodore Roosevelt's first visit to the South Rim in 1903, the region helped launch a new era of conservation. "Leave it as is," stated Roosevelt. "You cannot improve it. The ages have been at work on it and man can only mar it" (Newman 2011). In the years following his first visit, Roosevelt made several hunting and wilderness expeditions along the Canyon's North and South Rims, as well as into the Canyon itself. He commented on the great abundance of wildlife, and its unique appearance and austere beauty.

Fig. 6.4: View from the Saddle Mountain Trail, overlooking Nankoweap Trial, originally established by John Wesley Powell as a route to the river. Photo by Kristen M. Caldon.

Fig. 6.5 An aerial view of the original Grand Canyon Airport at Red Butte. Photo by Kristen M. Caldon.

Roosevelt proclaimed the Grand Canyon and its surrounding forests as a National Game Preserve in 1906 and as a National Monument 1908 (Newman 2011). He praised the beauty of the Kaibab Plateau – from the abundant wildflowers and towering pines, to Great Horned Owls and juncos. Some species he had no name for such as a "long-crested, dark-blue jay," known today as the Steller's Jay, and "the handsomest squirrels I have ever seen – with `black bodies and bushy white tails," unmistakably the Kaibab Squirrel, endemic to the Kaibab Plateau (Newman 2011). In contrast to the geological observations of Powell and Gilbert, Roosevelt made several important, critical observations about the ecology of the region, observations which continue to influence conservation efforts. In the few short years following its designation as a National Monument, Roosevelt noted an observable shift in the wildlife populations of the Kaibab Plateau. In his account of a cougar hunt in 1913, Roosevelt commented on the increasing numbers of the "chief game animal of the Colorado Canyon reserve… the Rocky Mountain blacktail, or mule deer," also known as the Kaibab desert mule deer (Newman 2011). Attributing this to a decrease in human hunting of deer as well as the killing off of cougars, Roosevelt documented a pivotal moment in the federal government's role managing wildlife on public lands (Binkley 2006).

At the time of his cougar hunt in 1913, the region was under designation as a National Monument. With a decrease in human hunting (mostly native peoples), and an increase in the number of cougars killed by rangers and hunters, species like the Kaibab deer and other game underwent a massive population explosion (Binkley 2006). Grand Canyon game warden, Uncle Jim Owens, reportedly killed between two and three hundred cougars during his tenure. Although it is easy to see that he did not understand the ecological importance of the big cats, he did admire their deadly skill as hunters, commenting on their social and predatory behaviors. Roosevelt maintained the opinion that removal of predators was an ecological service, enabling every man to better experience wild nature (Newman 2011). As a result of these early land discussions, the Canyon region and the animals and peoples who historically inhabited it during this early period of conservation underwent a drastic reconfiguration.

Almost two decades prior to its designation as a National Monument, the federal government declared the area as the Grand Canyon Forest Reserve (1893). The area encompassed the Havasupai reservation and created a barrier between the Havasupai and the forests where they had hunted for game, gathered for other foodstuffs, and grazed horses (Hughes 1978). The Tribe was not able to hunt beyond the reservation borders without game permits.

Transition of the Grand Canyon region from a Forest Reserve to a National Monument, and finally to its designation as a National Park in 1919, ultimately protected Grand Canyon and some of its wildlife from what Roosevelt called "selfish exploiters of the public domain" (Newman 2011). However, the initial impacts of these decisions resulted in massive population fluctuations of Kaibab deer and their natural predators. Overgrazing of aspen, continued predator control, and an increase in human hunting in the 1920s also had major impacts on deer and other wildlife species (Binkley 2006).

Tourism and development continued to increase after designation as a National Park. The cable car built by David Rust at Bright Angel Creek in 1903 was replaced in 1921 by a swinging bridge, and increased automobile traffic inspired Harold and Nina N. Bowman to open Jacob Lake Inn and filling station on the North Rim in 1923. Nina's grandfather, Franklin B. Woolley, authored the summary report of the 1866 cavalry exploration of southern Utah and northern Arizona in 1866 – an area that encompassed St. George, the Kaibab Plateau, and the mouth of the Green River (the chief tributary of the Colorado River). The report included the first official description and map of the Kaibab Plateau. Franklin's brother, Edwin D. Woolley Jr., as one of the first white men to see Grand Canyon from the North Rim. He predicted that people would come from "all corners of the globe and pay large sums of money to gaze at (this true) wonder of the world." Edwin guided the first automobile trip to the North Rim in 1913. He built a road along the way and shipped gas from the nearest filling station in Salt Lake City, a distance of 320 miles. Henry Bowman, Harold's father, also played a major role in improving automobile access to the Grand Canyon, building the first road from Kanab, Utah to Mt. Carmel.

Fig. 6.6 Ponderosa Pine dominates the forests of the proposed monument, and has played a seminal role in the history of the region. Photo by Jeri Ledbetter.

Fig. 6.7 Steller's Jay. Photo by Molly Joyce.

By the time Harold and Nina established their lodge in 1923, nearly 60 years of exploration, settlement, development, and legal battles had elapsed. The Jacob Lake Inn "was quite an experiment at first," stated Harold. "If we could sell a barrel of gas in one day, we thought we had had good business." It was not until the mid-1930s, after Navajo Bridge was constructed across the Colorado River at Marble Canyon and the crossroads of Highway 89A and Highway 67 south of the North Rim were completed, that their business was able to prosper.

The 1920s marked a decade of development and increased visitation to the South Rim as well. After completion of the rail line to the South Rim, and Bass improved his road to the South Bass area, tourists came by train and automobile to the southern portion of the proposed GGCHNM. In 1927, Parker Van Zandt created a runway and built an airplane hangar near Red Butte south of Grand Canyon Village. He launched the first air tours of the Grand Canyon and secured investors such as Henry Ford. Amelia Earhart and Charles Lindbergh both landed their planes at that airport. The aerial tour company, Scenic Airways Inc. remained open until the 1960s, when a more central airport was completed at Tusayan.

Summary

Grand Canyon is the focal point of tourism and visitation in northern Arizona, and the history of exploration and settlement continues to profoundly affect the landscape. From Cardenas and Escalante, to Lee, Roosevelt and modern entrepreneurs, these explorers and settlers shaped economic development along the Canyon's Rims. The history of the proposed GGCHNM has been a grand debate on balancing economic and environmental concerns over this vast, rich, scenic landscape, a discourse produced through the lives and actions of Native Americans, explorers, politicians, authors, and artists. Understanding the significance of this enormous suite of ecosystems, few could anticipate 5 million tourists would be drawn to the region annually in the 21st century.

American perception of the Grand Canyon changed dramatically over the past 500 years. People no longer cross the southwestern states with goals of imperialism, ignoring the natural and cultural significance of the GGCHNM landscape. Instead, the myth and grandeur of the region gradually dawned upon them. It has passed through generations of men and women whose personal ties to the Canyon evolved from exploration to settlement and by opportunistic pioneers, to recreation, pleasure seekers and those hungry for reconnection to the natural world. Hunting, logging, mining, damming, and tourism have altered the GGCHNM over the course of history, and the region continues to play an integral role in land and natural resource conservation philosophy and policy.

CHAPTER 7

LANDSCAPE CONSERVATION HISTORY

KIM CRUMBO AND KATIE DAVIS

INTRODUCTION

Concerns over degradation of the natural values of the Grand Canyon region led to the establishment in 1893 of a forest reserve surrounding Grand Canyon. In fact, between 1882 and 1886, Senator (later President) Benjamin Harrison introduced three Grand Canyon National Park bills that evidently included the North Kaibab (Morehouse 1996:39). In 1903, Theodore Roosevelt visited the region and pronounced: "The Grand Canyon fills me with awe. It is beyond comparison—beyond description; absolutely unparalleled throughout the wide world... Let this great wonder of nature remain as it now is. Do nothing to mar its grandeur, sublimity and loveliness. You cannot improve on it. But what you can do is to keep it for your children, your children's children, and all who come after you, as the one great sight which every American should see" (Hughes 1979:66). Roosevelt did much to protect the Grand Canyon, but he could scarcely foresee the ensuing century of struggle that lay ahead to preserve this great American treasure.

By 1905, Congress and President Theodore Roosevelt recognized that forests like the Kaibab should be set aside "for the wild forest creatures" …[to] afford perpetual protection to the native fauna and flora" (U.S. Congress 1905). In 1906, and in accordance with earlier Congressional authorization, Theodore Roosevelt established the Grand Canyon National Game Preserve for "the protection of game animals… recognized as a breeding place therefore…" That designation, while still on the books, has proven ineffective in preserving the full spectrum of native species and their habitat, especially large carnivores and the Plateau's old growth forests and grasslands.

Two decades after Roosevelt's Game Preserve designation, "Ding" Darling, the head of the U.S. Biological Survey, proposed creating a vast wildlife area on the Arizona Strip. At least one rancher, Preston Nutter, expressed enthusiasm for the idea (Price and Darby 1964:251). As usual, the principal opponents, ranchers (with at least one exception, Mr. Nutter) and loggers, blocked these conservation efforts (Morehouse 1996).

In 1908, Theodore Roosevelt, exasperated by faint-hearted congressional reluctance to protect the Grand Canyon, proclaimed the area a national monument, laying the foundation for the National Park but leaving out most of the forested Kaibab Plateau (Morehouse 1996:37). Efforts to protect the lands surrounding Grand Canyon continued with recommendations for an enlarged, five million-acre national monument including not only the North Kaibab and Tusayan Ranger Districts adjacent to Grand Canyon, but portions of Utah's Dixie National Forest (Morehouse 1996:40).

The Act of Congress, signed by President Woodrow Wilson, established Grand Canyon on February 26, 1919, three months after the end of World War I, in which 16 million humans perished. In 1927, Congress enlarged the

Park to include portions of the North Kaibab forest (Hughes 1979:90). In December 1932, Herbert Hoover, of all people, established a 273,145-acre Grand Canyon National Monument in the Toroweap region of western Grand Canyon (Morehouse 1996:73; Hughes 1979:90).

Traditional opponents to Park additions (logger, ranchers and hunters) emerged again in 1930 and by 1937, adversaries informed Arizona's Senator Hayden that ranchers opposed "loss of any more grazing range" (Morehouse 1996:75,76). Yet, greater threats to the Canyon lay just over the horizon.

In 1922, seven states and the federal government negotiated and signed the Colorado River Compact, defining the relationship between the upper basin states, where most of the river's water supply originates, and the lower basin states, where most of the water demands were developing (Law of the River 2012). At the time, the upper basin states were concerned that plans for Hoover Dam and other water development projects in the lower basin would, under the Western water law doctrine of prior appropriation, deprive them of their ability to use the river's flows in the future. The compact established Lee Ferry as divider between the Upper and Lower Basins (Hughes 1979:97).

One outcome of the compact, the U.S. Geological Survey headed by Claude H. Birdseye, lead an expedition down the Colorado River through Grand Canyon in 1923, intent on locating potential dam sites (Hughes 1979: 97; Lavender 1985: 58-65).

In 1950, the Bureau of Reclamation completed a grandiose scheme recommending two major dams in Grand Canyon National Park (Crumbo 1994). Marble Canyon Dam, planned for just below Red Wall Cavern at Mile 39.5, would have flooded 609 km of river up to near the base of Glen Canyon Dam, wiping out one of the world's most enchanting river canyons. A second dam, Bridge Canyon Dam at Mile 236, would have flooded 95 miles of river, including Lava Falls and the lower section of Havasu Creek.

As late as 1966, many considered the dams inevitable, but in June of that year, the Sierra Club paid for full-page advertisements in the New York Times and Washington Post: "Only You Can Save the Grand Canyon from being Flooded—For Profit" (Crumbo 1994). In 1968, after much debate, deceit and political maneuvering, Congress passed, and President Lyndon B. Johnson signed, Public Law 90-537 prohibiting the study or construction of hydroelectric dams in Grand Canyon without congressional approval.

On January 20, 1969, his last day in office, President Johnson created Marble Canyon National Monument (Hughes 1979:106). Finally, in 1975, President Ford signed the Grand Canyon Enlargement Act, embracing Marble Canyon and Grand Canyon (Toroweap) national monuments, and protecting the entire Canyon from Lees Ferry to the Grand Wash Cliff.

Water Flows

The Grand Canyon Protection Act of 1992 requires the Secretary of the Interior to "operate Glen Canyon Dam …in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park… including, but not limited to natural and cultural resources and visitor use." While this Act does not directly influence management of the proposed GGCHNM, it emphasizes the importance of Grand Canyon in regional land management.

Forest Management

Surrounded by desert and isolated by canyons, forests on the Kaibab Plateau have a unique evolutionary history (Keith 2003, Weng and Jackson 1999). The distribution of major forest vegetation types on the plateau generally follows gradients of temperature and moisture that correspond with elevation (Rasmussen 1941 – Figure 1). Ponderosa pine forest intermixes with pinyon-juniper woodland near canyon rims, and it is prominent up to approximately 8,200 feet above sea level, where it transitions to forest dominated Douglas-fir and spruce species. Quaking aspen is ubiquitous and transitional among all forest types on the Kaibab Plateau.

Old growth forests that feature large, fire-resistant ponderosa pine and Douglas-fir trees are less abundant today than when Europeans settled the region. Industrial logging removed more than 90 percent of old growth structure from ponderosa pine forests in the American Southwest by 1990 (Bailey and Ide 2001, Covington and Moore

1999, USDA 2007). Old growth is more abundant on the Kaibab Plateau due, in part, to its remoteness from commercial infrastructure and relatively short logging history (Sesnie and Bailey 2003). In fact, outside of designated wilderness areas, there is no other forested landscape in the Southwest that contains more old-growth trees and old-growth forest structure

Forest inventory data collected in 1982 and 1990 on the northern Kaibab Plateau near Jacob Lake, Arizona, showed that approximately 53 percent of ponderosa pine forest exhibited old growth structure (Sesnie and Bailey 2003). Contiguous old growth stands were even more common before 1940, when the U.S. Forest Service developed its first timber management plan for the Kaibab Plateau. Extensive timber harvest in the second half of the 20th century replaced old growth forest with even-aged stands dominated by small trees on approximately 45 percent of the plateau (Sesnie and Bailey 2003: 44-46; Figure 4).

In this regard, ponderosa pine forest structure and composition on the Kaibab Plateau changed in a qualitatively similar fashion to what occurred elsewhere as a result of human management (Covington and Moore 1999). However, the highest density of northern goshawks reported in North America occurs on the Kaibab Plateau primarily because the remaining late seral forest offers relatively abundant nesting habitat (Reynolds and Joy 1998). Objects of scientific interest on the plateau include the remaining old growth forest and associated wildlife populations that are more abundant on the Kaibab Plateau than anywhere else in the American Southwest.

Evidence from fire scars in live trees indicates that frequent, low-intensity surface fires were characteristic of ponderosa pine forests in the period from approximately 1700 to present (Swetnam and Baisan 1996). Fulé and others (2000) reported a mean fire return interval of six-to-nine (6-9) years in ponderosa pine forest on the southern edge of the Kaibab Plateau where lightning strikes are most common. At other plateau locations, mean fire return intervals ranged from five-to-19 years (Fulé et al. 2003, Wolf and Mast 1998). Fires generally occur in dry years, particularly when preceded by one to three years of high precipitation (Swetnam and Baisan 1996, Fulé et al. 2000).

Fulé and others (2002a, 2002b) noted spatial gaps in ponderosa pine forest stands comprising patches of about two (2) hectares or less where crown fires stimulated quaking aspen, indicating a mixed-severity fire regime (Odion et al. 2010, Williams and Baker 2012). According to Rasmussen (1941: 254), "The aspen attains its maximum development above the yellow pine, but areas and scattered groups are present in many parts of' the association. This species apparently forms a primary seral stage in the forest succession near the upper border of the community but it is also found in a variety of local situations."

Mixed conifer forest is transitional between ponderosa pine and spruce-fir communities. With inherently diverse composition and structure, mixed conifer forest exhibits an intermediate fire regime including low-severity and stand-replacing fires that maintain a patchy mosaic of vegetation over broad scales (Odion et al. 2014, Williams and Baker 2012). According to Fulé and others (2003: 483-484), the fire regime of mixed conifer forest varies by slope and aspect:

> *The transition zone studied here, changing from surface to stand-replacing fires, may be the most complex case for fire regime reconstruction. [E]ven if we were fully able to reconstruct the details of every fire from 1700 to 1879, the pattern of severe burning did not appear to be stable over the spatial and temporal scale of the study. These considerations imply that managers may be best advised to view the historical condition in high-elevation southwestern forests as a relatively general guide to reference conditions, in contrast to the more specific and temporally stable reference data available for lower-elevation ponderosa pine forests.*

Elevated densities of small, shade-tolerant, and fire-sensitive tree species like white fir may be an artifact of fire suppression in mixed conifer forest (Fulé et al. 2003), but the effect of fire suppression is not uniform across the Kaibab Plateau.

Frequent disturbance by lightning-ignited fires shaped the structure and composition of conifer forest on the Kaibab Plateau for at least 10,000 years before European settlement. A mixed-severity fire regime with short area rotations coincided with the invasion of ponderosa pine into mesic, spruce-dominated formations as regional temperatures increased at the beginning of the Holocene (Weng and Jackson 1999: 196-197).

Fire disturbance patterns occur in disequilibrium with current climate (Allen et al. 2002). The last decade of the 20th century and first decade of the 21st century were the warmest of the past millennium (Seager and Vecchi 2010). Xeric conditions that prevailed ~6,000 years ago may offer a better analogue to the emerging climate than what prevailed in the past few centuries (Mock and Brunelle-Daines 1999, Seager et al. 2007, Weng and Jackson 1999). Continued warming will necessitate restoration approaches informed by reference conditions drawn from deeper time than what existed when Europeans settled the area (Noss et al. 2006, Swetnam et al. 1999, Whitlock et al. 2003).

The relatively intact forests of the Kaibab Plateau are highly adapted to natural fire disturbances (Allen et al. 2002, Falk et al. 2006, Fulé et al. 2002b). Additionally, due to its remoteness and limited private acreage, the Kaibab Plateau contains few developed areas and is notable for its absence of structures or established human communities that have the potential to be disturbed by fire. This unique ecosystem presents significant management opportunities to accomplish restoration of natural disturbance processes, and provides ideal conditions to study and observe these phenomena.

Fire should be used to accomplish restoration objectives where it has been artificially suppressed by human management (Brown et al. 2004, DellaSala et al. 2004, Odion et al. 2014). Sustainable forest management will emphasize fire resilience as natural disturbances increase in frequency (McKenzie et al. 2004, Seager et al. 2007, Seager and Vecchi 2010, Weng and Jackson 1999, Westerling et al. 2006, Williams et al. 2010). Fire resilience will be especially important to conservation and recovery of sensitive wildlife species including northern goshawk, Kaibab squirrel, and Mexican spotted owl.

Fulé and Laughlin (2007) studied fire effects to conifer forest structure and composition on the Kaibab Plateau. Use of naturally-ignited wildfires in 2003 caused significant reductions of tree density, canopy cover, and fuel load on burned sites compared to sites that did not burn. "Thinning effects" of fire in ponderosa pine forest, even after fire had been excluded since 1880, was consistent with restoration objectives (Fulé and Laughlin 2007: 144). Therefore, the Kaibab Plateau presents the Forest Service, other state and federal agencies, and scientists with a rare chance to implement and study fire-based restoration projects, while protecting old growth forest characteristics, well into the future.

Natural Quiet

Aviators have found the Grand Canyon irresistible since at least 1919 when an Army Air Service pilot braved the canyon's depths by descending about 2,000 feet below the rim (Hughes 1979:100). Expansion of air travel led to construction of an airport in 1965, just outside the Park at Tusayan town (Hughes 1979:104. The airport soon became the state's third busiest as the Canyon's once immense silence filled with the whine of aircraft. Often, only the roar a large rapid could mask the often constant aerial drone, while it was not uncommon to find a helicopter hovering directly over the pools of Deer Creek Falls, or along the face of Thunder River. Not all approved. "The prevalence of airplanes and helicopters in and above the Grand Canyon," wrote Edward Abbey "are a distracting, irritating nuisance which should no longer be tolerated by anybody," and many agreed (Crumbo 1994). Public dissatisfaction resulted in passage of the 1987 National Parks Overflights Act. The Act required the agencies to "provide for substantial restoration of the natural quiet and experience of the park and protection of public health and safety from adverse effects associated with aircraft overflight." The fight to restore natural quiet continues to this day, although increases in overflight frequency have been proposed.

The Grand Canyon Watershed Protection Act of 2011

During the first session of the 112th Congress, Representative Raul Grijalva introduced legislation to protect Grand Canyon's immediate watershed outside the Park from additional uranium mining claims and subsequent mining impacts, as described above. The legislation failed to pass, but at public insistence the Secretary of Interior withdrew from future mining claims 1.7 million acres surrounding Grand Canyon National Park. As described in the Mineral Resources section of Hydrogeology Chapter 2, many uranium mining claims exist in the region and two are in or nearly in operation.

The withdrawal order was only for 20 years, and recently some lawmakers introduced legislation to overturn the Secretary's decision demonstrated Congress' unwillingness to provide long-term protection of the natural values critical to the region's economic and environmental welfare. At the time of this writing, at the mining industry has filed least four lawsuits seeking repeal of the withdrawal. Conservationists, led by the Sierra Club and Grand Canyon Wildlands Council are leading the charge to convince the President to follow Theodore Roosevelt's example and fulfill the vision to permanently protect the Grand Canyon on a grander and ecologically complete scale.

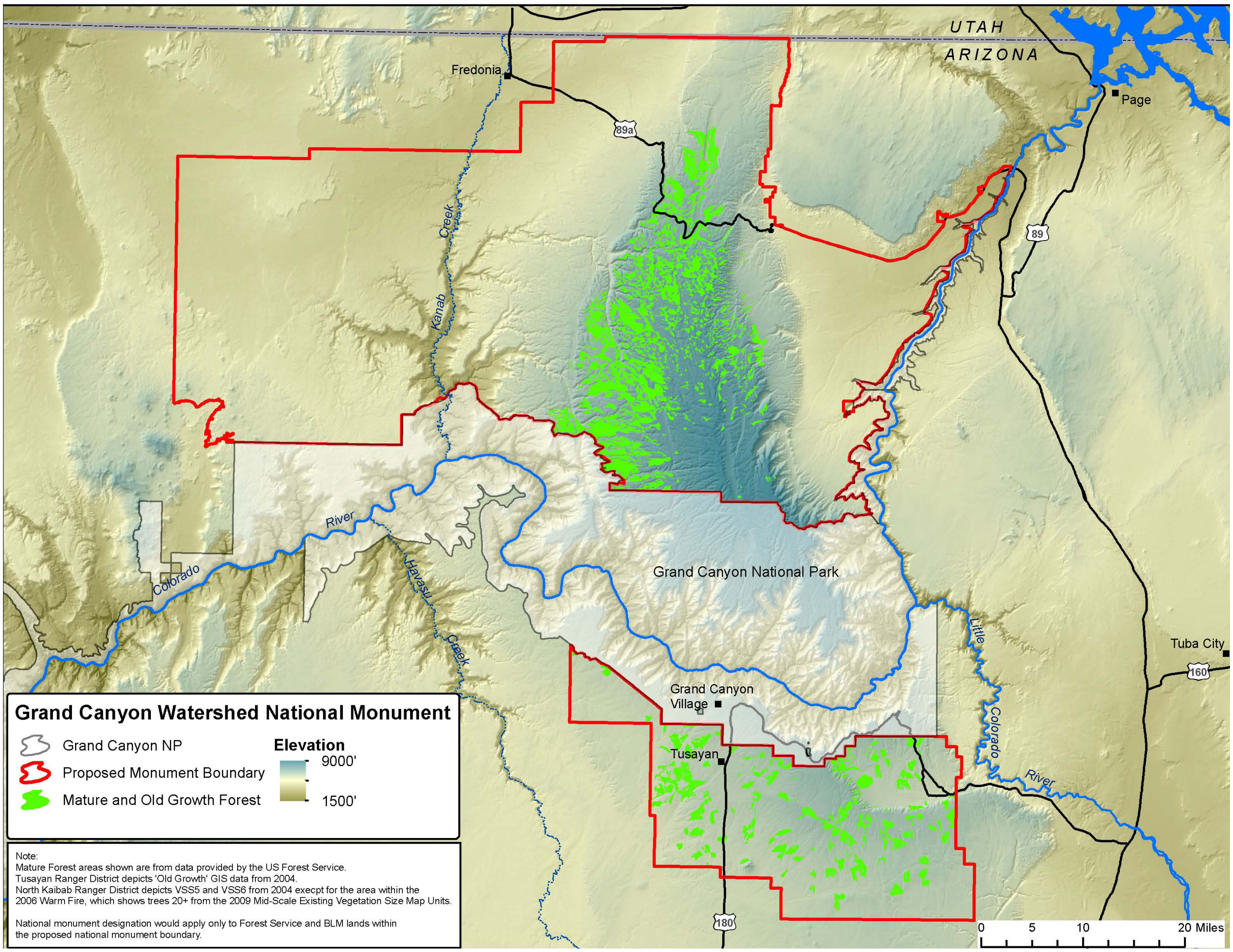


Fig. 7.1 Map showing the location and distribution of mature and old-growth forest structure on the Kaibab Plateau. Produced by the Center for Biological Diversity.

CHAPTER 8

TEN NOTABLE SCIENCE CHARACTERISTICS OF THE GGCHNM

UNIQUE GEOGRAPHIC SIGNIFICANCE

The proposed Greater Grand Canyon Heritage National Monument (GGCHNM) includes the Kaibab Plateau, House Rock Valley, and the southern part of the Kanab Creek drainage, as well as a portion of the Coconino Plateau immediately south of Grand Canyon National Park, spanning the Grand Canyon and forming its proximal watershed. Bordered on the west by the Shivwits Plateau, to the east by the Vermilion Cliffs, and on the north by Highway 89A and the Utah state line, the proposed monument captures a piece of western geography that has shaped the distribution of humans and wildlife across the southwest for millennia.

The GGCHNM's geographical significance is also due in large part to the unique geological history that resulted in the enormous East Kaibab Monocline, which elevates the North Rim of Grand Canyon more than 800 m above the South Rim. The geographical position of the GGCHNM encompasses the transition between the Colorado Plateau and the southern US desert biomes, influencing everything from the movement of water to the evolution of native species, this geographical and geological transition zone is of significant scientific value.

REMARKABLE HYDROLOGY

The GGCHNM region spans one of the most profound geological features in the United States, the chasm of Grand Canyon. The exposure of Colorado Plateau strata reveals not only the vastness of time that has transpired over Earth's history, but also provides a detailed look into the geohydrology that supports the aquifers and hydrologic cycle of this arid region. As such, the GGCHNM is a geohydrological laboratory, which can be studied to better understand how water moves through the Earth and how aquifers function. While the proposed GGCHNM does not, itself, contain many flowing streams, it protects the headwaters of a large number of pristine streams and contains numerous ecologically and culturally significant springs, seeps, and natural ponds.

CLIMATE CHANGE AND ECOTONE ECOLOGY

A remarkable paleoecological transformation has occurred in the GGCHNM over the past 50,000 years. The western margin of the GGCHNM roughly coincides with the boundary between the Sonoran/Mojave/Great Basin floristic provinces to the west, with the Maderan province to the south, and the Intermountain province to the northeast. Analysis of ancient packrat middens and cave deposits has revealed that the pinyon-juniper treeline rose 3,000 feet upslope in less than 7,000 years during the Pleistocene-Holocene transition, as a warmer, drier climate developed. These environmental shifts resulted in the mixing of plant species from the surrounding ecosystems and biomes. Environmental and floristic changes, coupled with the arrival of early humans, resulted in the extinction of the Pleistocene megafauna – elephants, camels, mountain goats, large predators, and giant birds that roamed the plateaus and lowlands, prior to natural desertification. On-going concerns over how ecosystems will function in response to global climate changes, can be examined through space-for-time studies across the elevation and aspect gradients that are so abundantly expressed in the GGCHNM region.

A Biological and Evolutionary Hotspot

Desert and plateau springs, karst cave systems, and old growth coniferous forest provide refugia and make the North Kaibab an important biological hotspot. The Forest Service manages more than 200 springs on the Kaibab Plateau, many of which harbor rare and sometimes unique life. The springs and habitats in the North Canyon drainage support at least 6 rare or endemic species of plants, invertebrates and endangered Apache trout. Many forest springs have been altered by human activities, but can be easily restored to ensure they remain hot spots for biodiversity: stoneflies, beetles, and various amphibians require springs wetland habitats.

A Refuge for Sensitive and Game Species

The GGCHNM region supports at least 1500 plant species, an extraordinary but poorly documented entomofanua with several endemic species, one endangered fish species, 6 amphibian species, reptile species, 112 bird species, and 79 mammal species. Several dozen Kaibab plant and animal species are rare or endemic, and are species of concern to the State of Arizona, the U.S. Fish and Wildlife Service, the U.S. Forest Service, or other federal agencies. The extent of migratory and upland species using the GGCHNM and its role as a corridor, flyway, and refuge demonstrate how critical the proposed monument landscape is to the persistence of those many iconic species and populations.

An Important Migratory Corridor

The long, north-south aligned escarpment of the East Kaibab Monocline has been identified as one of the primary hawk flyways in the Southwest. Cliffs such as these provide migratory pathways for hawks, eagles, and other species, which are well-documented. A large number of raptors migrate through southern Utah and use upwardly-rising air currents that develop as daytime mountain winds along cliff lines. The North Kaibab region provides a primary movement corridor for Desert Mule Deer, and likely other large mammals, such as Desert Bighorn Sheep, and Mountain Lion (*Puma concolor*) from lowland to upland habitats.

Population and Landscape Restoration Ecology

Restoration ecology is being explored and implemented in the region through several different projects. 1) The U.S. Forest Service has undertaken springs and forest rehabilitation projects. 2) Endangered California Condors have been released from a site on the Vermilion Cliffs near Marble Canyon, with more than 75 birds presently flying. 3) Pronghorn and Bighorn Sheep population restoration efforts have increased the herd and flock sizes. 4) Non-native tamarisk, an invasive woody tree, has been removed from several desert springs along Kanab Creek, and the impacts of tamarisk leaf beetles are being examined through northern Arizona. Overall, these population and ecosystem management activities demonstrate that the GGCHNM region is an extraordinary natural laboratory in which to test and apply the principles of conservation and restoration ecology.

Archaeology and Cultural Anthropology

Much of the current understanding of GGCHNM region archaeology is based on small-scale, superficial surveys, rather than on broad or detailed assessments. However, existing research has revealed Paleoindian artifacts from the region dating to perhaps >6,000 BC; quarries, campsites and chipping areas dating from the Archaic period (ca. 2500 to 300 BC), as well as numerous house sites dating to the Basketmaker II to Pueblo III periods (ca. AD 500-1150); and Southern Paiute occupation (ca. AD 1250-1880). Pictograph sites, caves (including some with feathered arrowshafts, sandals, and woven baskets) and rockshelters containing elaborate rock art have been discovered. These sites and remains are considered by contemporary American Indians to be significant cultural properties. Conservation and further inventory and study of these sites and remains will elucidate the complex relationships between early humans in the GGCHNM and Grand Canyon regions. These sites and remains are considered by contemporary American Indians as significant cultural properties.

A History of Exploration and Westward American Expansion

The color and harshness of the GGCHNM region is strongly reflected in its exploration and settlement history. Though the focal point of the region is the Canyon itself, a large portion of its history and development took place in the proposed GGCHNM. Expeditions led by European explorers resulted in the first documentation and interaction with Grand Canyon by those outside American Indian communities. As new settlers moved west from eastern America, early mountain men and pioneers created and maintained trails and villages throughout the proposed monument landscape. Interactions, both peaceful and violent, between American Indian tribes and European settlers influenced the politics and use of the lands and waters in the region. Industries such as cattle operations, mining, and timber harvest popped up, all of which played an important role in the development of local economies. The GGCHNM is a reflection of the dynamic and ever-shifting understanding of the role and influence of human development on the Grand Canyon region, all of which is of great historical importance for American Indian tribes and the American people.

A Vast, Scenic Landscape that Protects Grand Canyon

The GGCHNM region is a truly vast and largely undeveloped landscape, made more remote and inaccessible due to its geographical features. The Plateau, its escarpment margins, and the surrounding lands, have exceptional regional and global scenic, recreational, scientific, and cultural value. Protection of this region will provide a better buffer from the impacts of human development and climate change, helping to protect Grand Canyon from the onslaught of environmental disruption that so greatly threatens the ecological integrity of the Southwest.

Summary

This landscape analysis indicates that significant geological, biological and human history features and processes exist in the GGCHNM region, and additional research is likely to contribute substantial information to understanding the processes and impacts of geological, biogeographic, and global environmental change. The objects, features, and scientific opportunities mentioned herein, coupled with the overall high ecological integrity of most of the landscape, its low human population density and development, and few extractable resources, make the GGCHNM a prime opportunity for enhanced protection.

Protection of the GGCHNM region is not only a worthy undertaking in its own right, but it will help buffer Grand Canyon National Park from the impacts of rapid population expansion in southern Utah and Nevada, as well as threats just outside the Park. The region has outstanding scenic value, particularly along its eastern, southern and western escarpments. In addition, the proposed National Monument will provide better landscape linkage among the region's Wilderness Areas, protect prominent north-south migration routes, along with springs, caves, the Kanab Creek drainage, old growth forest stands on the Kaibab Plateau, and sensitive and game populations and their habitats on the northern portion of GGCHNM. Much remains to be learned about the GGCHNM region, and future inventories and studies are likely to substantially increase the list of species, identify important, as yet unrecognized, ecological processes, and how climate changes affect or are buffered in complex landscapes. Such data are only likely to further strengthen the rationale for preserving this geologically, biologically and anthropologically outstanding landscape.

An aerial view looking north across House Rock Valley, the East Kaibab Monocline, and the Vermillion Cliffs. Photo by Kristen M. Caldon.

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