National Park Service
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Natural Resource Stewardship and Science

Springs in the Mojave Desert Network—Vegetation Monitoring at Selected Large Springs

Protocol Narrative Version 1.0

Natural Resource Report NPS/MOJN/NRR—2018/1751



ON THE COVER
Photo of Saratoga Spring in Death Valley National Park in Spring 2017.
Photograph courtesy of the National Park Service (Nicole Hupp)

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Natural Resource Report NPS/MOJN/NRR—2018/1751

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September 2018

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Hupp, N. R., M. Lehman, and S. Wright. 2018. Springs in the Mojave Desert Network—vegetation monitoring at selected large springs: Narrative version 1.0. Natural Resource Report NPS/MOJN/NRR—2018/1751. National Park Service, Fort Collins, Colorado.

NPS 963/148510, September 2018

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Executive Summary

The Mojave Desert Network Inventory and Monitoring Program (MOJN) is one of 32 National Park Service (NPS) inventory and monitoring (I&M) networks nationwide. These networks monitor vital signs– indicators of ecosystem health – to assess the condition of park ecosystems. MOJN monitors natural resources in nine park units in Arizona, California, and Nevada: Castle Mountains National Monument (CAMO), Death Valley National Park (DEVA), Great Basin National Park (GRBA), Grand Canyon-Parashant National Monument (PARA), Joshua Tree National Park (JOTR), Lake Mead National Recreation Area (LAKE), Manzanar National Historic Site (MANZ), Mojave National Preserve (MOJA), and Tule Springs Fossil Beds National Monument (TUSK).

In 2002, the MOJN I&M program, in consultation with the MOJN parks, identified and prioritized vital signs for monitoring (Chung-MacCoubrey et al. 2008). Through this process, park superintendents and resource managers agreed that monitoring the vegetation at rivers and springs is a high priority resource management concern. Monitoring this vital sign will take place at the MOJN parks that have identified desert springs as a priority resource: DEVA, JOTR, LAKE, MOJA, and PARA.

The purpose of this monitoring protocol is to gather baseline data about desert spring vegetation and document changes in community composition in Mojave Desert springs. To achieve these goals, this protocol asks two monitoring questions: 1) What are the status and trends in plant community composition at select desert springs in MOJN parks? 2) How is species diversity and richness associated with human-related and natural disturbances changing over time? To address these questions, the measurable objectives are:

1. Determine status and long-term trends in plant species composition and richness (e.g., percent cover, number of different species) in selected springs of management concern in MOJN parks.

2. Determine status and long-term trends in the distribution and abundance (e.g. plant cover, number of plants) of target invasive plant species at selected springs in MOJN parks.

3. Determine status and long-term trends in the distribution and abundance (e.g., canopy, tree size) of overstory tree species of special management interest at selected springs in MOJN parks.

4. Determine status and long-term trends of natural and anthropogenic disturbances measured by the percentage of the site impacted by some human activity (e.g., grazing, recreational vehicles, other disturbances) at selected springs in MOJN parks.

Accomplishing these monitoring objectives will allow resource managers in the MOJN parks to assess desert spring vegetation condition, and target limited personnel time and financial resources toward addressing the highest priority management concerns. Additionally, sharing information regarding vegetation at unique springs and their condition with park visitors will enhance visitor experiences and contribute to protecting these fragile ecosystems.

Acknowledgments

Parks in the Mojave Desert Network contributed many hours to visiting sites, refining goals, and proofreading many versions of this protocol. We would like to acknowledge all of the personnel in MOJN parks that contributed to this, including members of the MOJN Technical Committee and other park staff particularly, Carrie Norman (LAKE), Neil Frakes (JOTR), Josh Hoines and Kirsten Lund (DEVA), Gretchen Baker and Meg Horner (GRBA), Jennifer Fox (PARA), and Drew Kaiser and Debra Hughson (MOJA). Geoff Moret at USGS began the foundations of this document and provided valuable advice. Additionally, early versions of this document were created by Wendy Trowbridge and Nita Tallent.

List of Acronyms and Abbreviations

BLM: Bureau of Land Management

DEVA: Death Valley National Park

DS: Desert Springs Monitoring Protocol; Moret et al. 2018 is a long-term monitoring protocol implemented in MOJN parks that inventories and monitors the status and trends at smaller and less-persistent MOJN springs.

GRBA: Great Basin National Park

I&M: Inventory and Monitoring

IPSED: Invasive Plant Species Early Detection Monitoring Plan; Hupp et al. 2017 is a monitoring plan MOJN developed to assist parks with identifying species of concern, detecting them, and outlines a plan to have those species treated.

JOTR: Joshua Tree National Park

LAKE: Lake Mead National Recreation Area

LAKE-EPMT: Lake Mead Exotic Plant Management Team

LPI: Line Point Intercept sampling is a vegetation monitoring method that collects data at points along a transect line. It is a rapid, accurate method for quantifying soil cover, including vegetation, litter, rocks and biotic crusts.

MANZ: Manzanar National Historic Site

MOJA: Mojave National Preserve

MOJN: Mojave Desert Network Inventory and Monitoring Program

NPS: National Park Service

PARA: Grand Canyon- Parashant National Monument

SLS: Selected Large Spring Protocol; Moret et al. 2016 is the MOJN protocol that measures water quality, quantity, and other hydrology elements at large, persistent springs of interest in MOJN parks.

SOP: Standard Operating Procedure

TUSK: Tule Springs Fossil Beds National Monument

US EPA: United States Environmental Protection Agency

USGS: United States Geological Survey

WRD: Water Resources Division

Background, Rationale, and Objectives

Background on Riparian and Spring Ecosystems

Riparian ecosystems are located in any area "which adjoins, directly influences, or is influenced by a body of water" (Lovett and Prince 2007). These places comprise less than 1% of the land area but are among the most productive ecosystems in North America (Johnson and Jones 1977). In the arid Southwest, riparian areas account for a dramatically disproportionate share of the biodiversity in the region (Holstein 1984). Vegetation in riparian ecosystems are mesic vegetative communities which include obligate species, phreatophytes (those that access groundwater through their roots), and facultative species. There is a swift transition from these species to upland vegetation which is more tolerant of arid conditions (Figure 1).

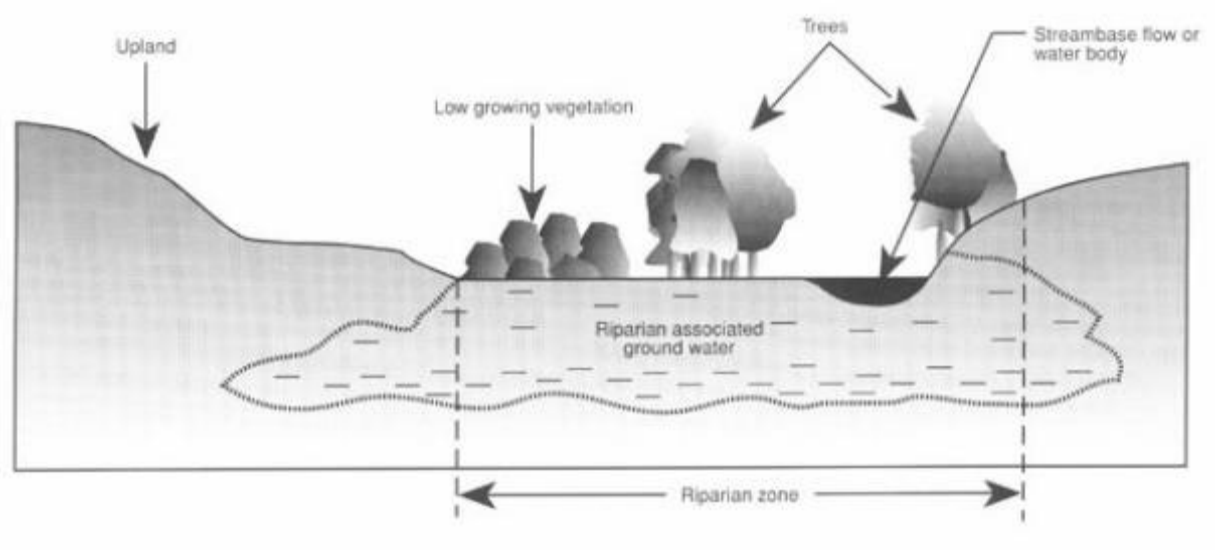


Figure 1. The major components of riparian areas include water, dense mesic vegetation, and a rapid transition to upland vegetation. The topography and hydrogeology of the spring determine the associated plant and animals communities. Vegetation in the riparian zone is often dense in multiple strata (figure adapted from http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/?cid=nrcs143_014199).

While the Mojave Desert has noteworthy rivers, including the Amargosa, Colorado, and Virgin Rivers, much of its riparian habitat is found at desert springs and oases. Springs and seeps are generally small aquatic systems that occur where groundwater emerges at the surface. These springs are commonly small and isolated, yet provide important sources of surface water for the region (Skudlarek 2006, Sada et al. 2001). The presence of that surface water and access to shallow groundwater is a fundamental difference between the ecosystems at desert springs compared to upland vegetation.

Parallels between Riparian Vegetation in the West and Desert Spring Vegetation of the Mojave Desert

Riparian zones in the West are uncommon on the landscape, but vegetation in these zones has an extensive history of research due to the importance of water resources and their corresponding

habitat for humans, wildlife, and all surrounding ecosystems (Elmore and Beschta 1987, Knopf et al. 1988). There are multiple comprehensively-tested riparian vegetation protocols in the West which have led to an accumulation of compelling baseline data in monitored riparian areas (Kershner et al. 2004, USFS 2014); such monitoring programs provide invaluable information regarding the status and health of those systems. Desert springs are less commonly the subjects of long-term research and monitoring (e.g. Coachella Valley Water District 2012, US Forest Service 2012, Stevens et al. 2016), and there is much to be learned about the vegetation at desert springs. This protocol contributes to springs vegetation information on National Park units located in the Mojave Desert Network.

Biodiversity Hotspots

Springs comprise a relatively small amount of the desert's land area but support a disproportionate amount of biodiversity (Hubbs 1995). From a conservation perspective, desert springs are keystone ecosystems: they require small investments of conservation resources, but have big returns because of the widespread influence of desert springs on the ecosystem (Hunter et al. 2017). These "biodiversity hotspots" are heavily used by desert wildlife as well as aquatic species (Fisher et al. 1972, Williams and Koenig 1980, Everett 1987, Myers and Resh 1999, Kreamer et al. 2014). Further, since springs are pockets of moisture that are rare and spatially disconnected, many are truly unique (Shepard 1993). Harsh upland habitats between isolated desert springs can prevent gene flow, causing desert springs to function as islands of habitat and often support endemic organisms and assemblages (e.g. MacArthur and Wilson 1967, Liu and Hershler 2008, Wood et al. 2012).

Many hundreds of species or subspecies of aquatic and wetland organisms are endemic to western U.S. springs. Some endemic taxa include: plants (Beatley 1977), mollusks and crustaceans (Hershler 1998, Hershler 1999, Hershler and Sada 1987, Sada and Vinyard 2002), dragonflies (Stevens and Bailowitz 2009), aquatic predatory bugs (Hemiptera; Polhemus and Polhemus 2002, Stevens and Polhemus 2008), caddisflies (Wiggins and Erman 1987), riffle beetles (Shepard 1993, Schmude 1999), and fishes (Hubbs and Miller 1948, Minckley et al. 1986). These endemic species are inherently delicate because they only exist in one localized place, and if that place is ecologically impaired, the species may be lost (e.g. Williams et al. 1985). This concern has led many ecologists to push for more inventory, ecological assessment, conservation research, and restoration of aquatic obligate taxa and springs throughout the West (Nevada Springs Restoration Workshop Committee 2012, Hershler et al. 2014).

Riparian areas are key habitat for wildlife, both resident and migratory, throughout the Mojave Desert. Birds and bats not only require water, they have specific requirements for the vegetation at desert springs. Fleishman et al. (2003) found that bird species in the Mojave Desert depend on riparian vegetation for habitat, where bird species richness is positively correlated with total vegetation volume. Further, they found the species composition of birds between study sites was more similar when plant composition was more similar, and vice versa, indicating a species-specific relationship between birds and vegetation. Similarly, other wildlife such as bats has species-specific habitat requirements at springs. Williams et al. (2006) found that 16 bat species in southern Nevada not only relied almost entirely on riparian areas for habitat and forage, but those species were highly specialized on different plant community types within the riparian areas. For example, Williams et al.

(2006) found 50% of all bats required riparian woodlands which comprise less than 1% of the total riparian area sampled.

Other mammals also rely on desert springs, a reliance that varies among species temporally and spatially. Among non-volant mammals, Ordway and Krausman (1986) tracked desert mule deer (*Odocoileus hemionus crooki)* in the Sonoran Desert and found that deer rely on water sources year round, but especially during early and late summer. Similarly desert bighorn sheep (*Ovis canadensis nelsoni*) in the Sonoran Desert relied on riparian vegetation for forage during the hottest months of the year, particularly ironwood (*Olneya tesota*) and catclaw acacia (*Senegalia greggii*) (Tarango et al. 2002), both of which are also common at Mojave Desert springs. The federally endangered Amargosa vole *(Microtus californicus scirpensis)* is a wetland obligate vole endemic to low-gradient, springs-supported reaches of the Amargosa River (U.S. Fish and Wildlife Service 2009).

Springs demonstrate a wetland-upland distribution, with a strong shift in the vegetation with increased proximity to water (Abella et al. 2014). Among the plants most dependent on water sources, desert springs host overstory species such as Fremont cottonwood (*Populus fremontii*) and woodlands of catclaw acacia (*Acacia greggii*), honey mesquite (*Prosopis glandulosa*), and screwbean mesquite (*Prosopis pubescens*). These woodlands support a diverse array of understory species including annuals, biennials, and perennial species (Abella and Chittick 2014).

Cultural Resources at MOJN Desert Springs

Just as wildlife and plants find refuge at desert springs, so have humans. Many of the springs in MOJN parks contain important cultural resources that document recent human use and Native American activity. These locations often are restored and preserved in the park units, and are the frequent destination locations for park visitors and Tribal members. Information about cultural history of each of the MOJN springs of interest is provided in each “Cultural History” description below.

Desert Spring Ecosystem Services

Beyond direct human and wildlife use, healthy riparian and aquatic ecosystems provide ecosystem services and benefits that have received only limited research attention. Such benefits can be challenging to define and quantify, but include clean water for diverse aquatic communities, freshwater for human consumption, natural flood, and erosion control (see Mitsch et al. 2015 and associated special issue research), and recreational opportunities that enhance the quality of life (Gregory et al. 1991, Baron et al. 2002). However, definition and quantification of springs ecosystem services in the Mojave Desert has not yet been published to our knowledge, although such analyses have been conducted for wetlands (e.g., Zedler and Kercher 2005).

Threats and Concerns

The dominant threats to riparian ecosystems include plant invasions, decreased community function due to nitrogen deposition, groundwater draw-down from commercial or residential developments, damage from grazing, reduced air quality, and climate change (Stevens and Meretsky 2008, Webb 2009, Kreamer et al. 2014, Stevens et al. 2016). At the root of many of these issues are anthropogenic disturbances, which have salient impacts on desert springs. Most of the larger springs in the Mojave

Desert, and in the United States as a whole, have sustained substantial human impacts for the past 12,000 years; this is demonstrated by the great number of late Pleistocene megafaunal fossils from springs that show clear evidence of human depredation (e.g., Haynes 2008). Thus, there is likely no such thing as a Mojave Desert springs ecosystem that is free from persistent, long-term human impacts. We anticipate these disturbances will continue in the future.

Invasive plant species have, and will likely continue to have, lasting complex impacts on desert riparian areas. Tamarisk (*Tamarix* spp.) is one of the most intensively studied invasive species in the desert due to its both negative (Zavaleta et al. 2000) and positive effects on the structure and function of riparian ecosystems (Stromberg 2009). Negative impacts of tamarisk include increased frequency of fires (Busch and Smith 1993, Drus 2013), reduced biodiversity (Harms and Hiebert 2006), reduced habitat quality for wildlife (Rice et al. 1980, Bailey et al. 2001), reduced fungal associations for foundation species (Hultine et al. 2015), and reduced ecosystem services as a whole, mostly a consequence of depletion of groundwater via transpiration (Zavaleta 2000, Shafroth et al. 2005). Despite these negative impacts, tamarisk foliage provides sufficient wildlife habitat for some species (Fleishman et al. 2003, Chew 2009). Introduction of the biocontrol beetle to defoliate tamarisk has recently been shown to have strong negative impacts on bird density (Darrah and Ripper 2017), arthropods, and herptofauna (Bateman et al. 2015). Invasive annual grasses, particularly red brome (*Bromus rubens*) and cheat grass (*Bromus tectorum*), also pose serious concerns due to their influence on fire regimes (D'Antonio and Vitousek 1992). Fires have historically been infrequent in the Mojave, but from 1980-2004 fires increased in frequency at middle elevations, resulting in an invasive plant-fire regime that may persist into the future (Brooks and Matchett 2006).

Non-native burros (*Equus asinus)* are sources of disturbance that exacerbate existing issues by promoting invasive plant species occurrence and severely reducing native perennial abundance (see review by Abella 2008). Despite the damage they inflict, burros are protected by the 1971 Wild Free-Roaming Horse and Burro Act in MOJN parks. These mammals have the highest abundance in the United States in the Mojave Desert, which creates thought-provoking tradeoffs between animal protections and environmental degradation due to non-native organisms.

Livestock grazing is also a permissible activity in many MOJN parks that has complex effects on desert springs. In a thorough review of riparian ecosystem grazing research by Belsky et al. (1999), livestock grazing was found to negatively affect water quality and seasonal quantity, stream channel morphology, hydrology, riparian zone soils, instream and streambank vegetation, and aquatic and riparian wildlife. No positive environmental impacts were found. Brooks (1995) investigated the effectiveness of cattle fencing in the Mojave Desert and found areas protected by fencing had high percent cover of perennial shrubs and higher seed biomass.

In a recent report, Sada and Lutz (2016) inventoried 2,256 springs from the late 1980s-2013 in the Great Basin and Mojave deserts found that most of the inventoried springs are disturbed by natural or anthropogenic sources. Of the sampled springs, 3% were disturbed by natural factors, and 83% had evidence of anthropogenic disturbance. Further, approximately 65% of sampled springs displayed moderate or high levels of disturbance by either diversion, horse, burro or cattle use, recreation, or dredging, and many springs were degraded by more than one of these uses. Recent studies by

Keleher and Radar (2008) and Sada et al. (2015) show that these levels of disturbance represent highly degraded, unhealthy ecosystems.

This past and present disturbance means that determining a "baseline" for these springs, a true undisturbed state, is effectively impossible. However, it is possible to understand ecosystem structure and function, assess conditions, and monitor changes. This process is particularly valid for springs, and can improve understanding of the role of disturbance dynamics in springs plant assemblages. Long term monitoring is particularly important in understanding these springs subject to large-scale, long term threats, such as climate change.

Rationale for Monitoring Spring Vegetation in the Mojave Desert Network

Long-term ecological monitoring is integral to the management and protection of the lands entrusted to the NPS. Long term data will allow managers to better identify threats in this extremely fragile ecosystem The NPS monitoring protocol presented here balances the short term needs for information about proximal threats such as grazing and invasive species with needs for long-term, large-scale information about community dynamics and climate change in desert springs habitats.

National Park Service enabling legislation, the 1916 Organic Act (NPS 1916), directed the NPS to work "within the established water regulatory system while preserving the scenery, natural and historic objects and wildlife, and provides for the enjoyment of same in ways that leave them unimpaired for future generations." In 1999, the NPS approved the Natural Resource Challenge (NPS 1999a), which stated, "The protection of National Park waters, watersheds, and aquatic life is fundamental to maintaining the integrity of natural resources and the quality of the visitor experience in the parks. Protective standards, scientific monitoring, and a program to ensure the protection of water quality, natural flows, and the health of aquatic systems are required to measure and protect this critical environmental component."

The hydrologic elements of springs are relevant for spring vegetation, and are monitored in detail following two MOJN monitoring protocols, Springs in the Mojave Desert Network: Water Quality and Quantity Monitoring at Selected Large Springs (SLS; Moret et al. 2016) and Springs in the Mojave Desert Network: Surface Water Monitoring at Desert Spring (DS; Moret et al. 2018). This protocol focuses on vegetation while the SLS and DS protocols address the groundwater dynamics and chemistry, surface water dynamics, and surface water chemistry vital signs.

Monitoring Locations

This protocol will focus on the spring vegetation in five of the desert parks (DEVA, JOTR, LAKE, PARA, and MOJA). MOJN parks not included in this protocol either have no desert springs (MANZ and TUSK), or have springs that are not isolated, but rather have groundwater inputs into streams (GRBA). While there are many springs located throughout the five parks of interest (Table 1), we used several criteria to select 3-5 springs per park to monitor in this protocol. The rationale for selection of those specific springs is explained in detail in the following section.

Table 1. Summary of MOJN Springs Inventory. From 2005-2010 MOJN conducted an inventory of springs throughout the network. The total number of springs inventoried, the park total area and elevation range, and the elevation range where springs were found are displayed below (Chung-MacCoubrey et al. 2008, Sada et al. 2009).

Park	Total Park Area (ha)	Elevation Range of Park (m)	# Springs and Seeps inventoried	Elevation of springs (m)
Death Valley NP (DEVA)	1,374,420	-86 to 3,368	1025	-81 to 2,915
Joshua Tree NP (JOTR)	321,327	0 to 1,772	292	320 to 1,619
Lake Mead NRA (LAKE)	521,346[a]	152 to 1,719	89	208 to 1,072
Mojave Nat'l. Pres (MOJA)	647,497	274 to 2,438	264	258 to 1,827
Grand Canyon-Parashant NM (PARA)	424,242[b]	366 to 2,447	221	387 to 2,250
Total	3,261,258	-86 to 3,368	1891	-81 to 2,915

[a] Excludes 84,358 hectares of NPS-owned land currently within LAKE boundary that is now part of PARA; Total park acreage for LAKE including NPS-owned land within PARA is 605,704 hectares.

[b] Total size of PARA includes 84,358 hectares of NPS-owned land, 327,288 hectares of BLM-managed lands, and 12,595 hectares of non-federal lands.

Park Descriptions

The geography of the five parks monitored in this protocol is summarized briefly below; each of the park missions include preserving park resources such as desert springs (Table 2). An overview of the desert springs in each parks follows in the subsequent section. MANZ, TUSK, and GRBA are MOJN Parks (see Figure 2 below for MOJN map) not included in this protocol due to their lack-of-fit for the protocol objectives, and are not discussed further.

Table 2. Mission Statements for Mojave Desert Network parks included in this protocol.

Park Name	Park Mission Statement [a]
Death Valley National Park (DEVA)	Death Valley National Park dedicates itself to protecting significant desert features that provide world class scenic, scientific, and educational opportunities for visitors and academics to explore and study (NPS 2002a).
Joshua Tree National Park (JOTR)	The National Park Service at Joshua Tree National Park preserves and protects a representative area of the Colorado and Mojave deserts and the natural and cultural resources for the benefit and enjoyment of present and future generations. The park includes rich biological and geological diversity, cultural history, recreational resources, and outstanding opportunities for scientific study (NPS 1995).
Lake Mead National Recreation Area (LAKE)	We provide diverse inland water recreational opportunities in a spectacular desert setting for present and future generations (NPS 1994).
Mojave National Preserve (MOJA)	Mojave National Preserve was established to preserve outstanding natural, cultural, and scenic resources while providing for scientific, educational, and recreational interests (NPS 2002b).

[a] Mission statements obtained from park General Management Plans

Table 2 (continued). Mission Statements for Mojave Desert Network parks included in this protocol.

Park Name	Park Mission Statement [a]
Grand Canyon-Parashant National Monument (PARA)	Grand Canyon-Parashant is a model of land management for the BLM and NPS that conserves its natural, scientific, and historic resources and includes ecological restoration and protection in a broad ecosystem context, while honoring the history and living traditions of the people who came before us: "the place where the west stays wild." (NPS 2008b)

[a] Mission statements obtained from park General Management Plans

Death Valley National Park (DEVA) was established in 1933 by Presidential Proclamation from President Herbert Hoover, "Whereas it appears that the public interest would be promoted by including certain lands known as Death Valley, in California, within a national monument of the preservation of the unusual features of scenic, scientific, and educational interest therein contained" (No. 2028-Feb. 11, 1933-47 Stat. 2554). Death Valley National Monument was enlarged in 1937, when President Franklin Roosevelt signed a supplementary Presidential Proclamation (No. 2228-50 Stat.1823) increasing its size from 648,226 ha (1,601,800 ac) to 836,806 ha (2,067,793 ac). In 1952, President Harry S. Truman further enlarged the monument by adding Devil's Hole (16 ha or 40 ac), which is home to the endangered Devil's Hole pupfish (*Cyprinodon diabolis*), through an additional Presidential Proclamation (No. 2961). Devil's Hole is located in Nye County, Nevada, and is disjunct from the rest of the monument (Unrau 1997). In 1984, Death Valley National Monument became part of the UNESCO Man and Biosphere Program as the main feature of the Mojave and Colorado Desert Biosphere Reserve.

Death Valley National Monument became Death Valley National Park in 1994 as part of the California Desert Protection Act (PL 103-433); it was one of the three NPS units established as part of the Act. As part of its establishment, ~510,000 ha (1.27 million ac) were added to DEVA, bringing it to almost 1.37 million ha (3.4 million ac), most of which is designated wilderness, making it the largest park in the lower 48 states. Today, DEVA includes all of Death Valley, which is 156-mile-long and formed between two major mountain ranges, the Amargosa Range on the east and the Panamint Range on the west, and the Saline, Eureka, northern Panamint, and Greenwater valleys. Death Valley is located in the transition zones between the Mojave Desert, the Great Basin, and the Whites and Inyo portion of the Sierra Nevada Range. The lowest point in North America is found in DEVA (Badwater, -86 m below sea level), which is also the base for the greatest elevation gradient in the contiguous United States. DEVA's wide diversity of habitats, including sand dunes, desert scrub, pinyon-juniper forests, bristlecone pine forests, sagebrush shrubland, springs, riparian corridors, marshes and subterranean pools, are home to over 1,200 native plant species, including fifty locally and regionally endemic species that have adapted to DEVA's unique and varied environment (NPS 2002a).

Joshua Tree National Park (JOTR) was founded in 1936 through a Presidential Proclamation (No. 2193 50 Stat. 1760) by President Franklin D. Roosevelt because its "lands contain historic and prehistoric structures and have situated thereon various objects of historic and scientific interest."

Originally, 334,003 ha (825,340 ac) was set aside as Joshua Tree National Monument to preserve an ecologically dynamic region of the California Desert, a transition zone between the Colorado and Mojave deserts (NPS 1999b). However, the size of the monument was reduced by 117,156 ha (289,500 ac) (PL 837, 64 Stat. 1033) by Congress in 1950 in order to allow for mining on former monument lands (i.e., Eagle and Pinto Mountains). In 1950, the Twentynine Palms Corporation donated the Oasis of Mara (~24 ha or 58 ac) to the monument, which was authorized by Congress in 1961, as a detached unit for the purpose of administrative and visitor center facilities. In 1984, Joshua Tree National Monument, along with Death Valley National Monument, became part of the UNESCO Mojave and Colorado Desert Biosphere Reserve.

Joshua Tree National Monument became Joshua Tree National Park in 1994, as one of three NPS units established as part of the California Desert Protection Act (PL 103-433). As part of JOTR's establishment, 94,696 ha (234,000 ac) were added, bringing the park to over 319,702 ha (790,000 ac), of which almost 75% is designated wilderness. JOTR is the southern-most park in MOJN and lies at the transition between the Mojave and Sonoran deserts and within the west-east oriented Southern California Mountains. In this compressed transition zone between three ecosystems, the park supports a unique diversity of desert flora and fauna. Currently, the western boundary of the park lies along the Little San Bernardino Mountains, part of the Transverse ranges, the southern edge along the base of the mountains that form the north perimeter of the Coachella Valley, the eastern edge includes the Coxcomb Mountains, and the Morongo Basin defines the north boundary (NPS 1995). The major valleys in JOTR include the Pinto Basin, Juniper Flats, Covington Flats, Pleasant, Queen, and Lost Horse. With the compressed transition zone between the Mojave Desert (on the western side of the park) and the Colorado Desert (on the eastern side of the park) at JOTR, it is possible to cross from one desert to the next in less than 65 miles. Creosote bush (*Larrea tridentata*), ocotillo (*Fouquieria splendens*), and palo verde (*Cercidium floridum*) dominate the Colorado desert portion of JOTR, while the famous Joshua tree stands (*Yucca brevifolia* var. *brevifolia*) occupies the Mojave Desert part of the park. The western part of the park is higher than the eastern part of the park, averaging 1,219 m (4,000 ft) to 610 m (2,000 ft) above sea level, respectively, and is slightly cooler and wetter. JOTR is well known for its five fan palm oases, an unusual feature in desert systems (NPS 1999b).

Lake Mead National Recreation Area (LAKE) formed by the damming of the Colorado River by Hoover Dam in 1935 (NPS 1994). While the Bureau of Reclamation maintained control of the dam, power plant, and reservoir, NPS was brought in to administer and develop recreational facilities along the lake and surrounding land that was part of the Reclamation withdrawal through a memorandum of agreement in 1936. This unit along the lake was named the "Boulder Dam Recreation Area." In 1947, the recreation area was enlarged through the addition of the proposed Lake Mohave, which was to be formed after the completion of Davis Dam (in 1951), near Laughlin, NV. In 1964, Boulder Dam Recreation Area officially became a unit of the NPS when President Lyndon Johnson signed an act (Public Law 88-639; 78 Stat. 1039) establishing the area as the Lake Mead National Recreation Area for "the general purpose of public recreation, benefit and use, and in a manner that will preserve, develop, and enhance … the recreation potential, and in a manner that will preserve the scenic, historic, scientific, and other important features of the area …" (NPS 1994).

LAKE supports a diversity of water based recreation for over eight million visitors per year and is among the premier inland water recreation areas in the West.

The boundaries of LAKE have changed since its establishment in 1964, with the Grand Canyon part of the recreation area transferred to Grand Canyon National Park and the Shivwits Plateau portion becoming part of the Grand Canyon-Parashant National Monument. Today, LAKE is the 4th largest NPS unit in the continental US with an administrative boundary of nearly 607,000 ha (1.5 million ac), 60% of which is in AZ and 40% in NV, with almost 27,316 ha (67,500 ac) of designated wilderness (NPS 2010b). It is bounded on the north by the town of Overton, NV, the Virgin Mountains, and PARA, on the east by Grand Canyon National Park, PARA, and the Black Mountains, on the south by Bullhead City, AZ, and Laughlin, NV, and on the west by Boulder City, NV, the Eldorado Mountains, and Newberry Mountains. In addition to Lakes Mead and Mohave, major features of LAKE include the Black Canyon, Boulder Canyon, Fortification Hill, Newberry Mountains, Black Mountains, Pinto Valley, and Redstone.

LAKE lies along the northeast boundary of the Mojave Desert and includes a portion of the high Colorado Plateau ecosystem on its eastern edge. The Colorado River reservoirs and associated lake shoreline, a reach of the Las Vegas Wash (a natural intermittent stream used to discharge the region's treated wastewater to Lake Mead), and the recreation area's desert springs preserve one of the Southwest's most threatened habitats – the desert riparian community. As a result, there are significant populations of many species of special concern in the park. LAKE is also a popular inland water recreation area and the primary source of drinking water for southern Nevada.

Mojave National Preserve (MOJA) was the third park unit established by the 1994 California Desert Protection Act (PL 103-433), at which time the former "East Mojave National Scenic Area," administered by the BLM, was transferred to the NPS and renamed. Although DEVA and JOTR were representatives of the Mojave Desert region, MOJA was established because the previous two parks "do not embrace the particular ecosystems and transitional desert type found in the Mojave Desert area lying between them on public lands now afforded only impermanent administrative designation as a national scenic area." MOJA protects a significant portion of the eastern Mojave Desert (Nystrom 2003).

MOJA is the third largest national park unit in the continental United States, at nearly 647,000 ha (1.6 million ac), ~44% of which is designated wilderness. The boundaries of MOJA on the north and south are major interstate highways, I-15 and I-40, respectively, the Nevada–California state line on the east, and parts of the Union Pacific Railroad on the west. Major features of the Preserve include Kelso Dunes, dry lakebeds, evidence of volcanic activity (domes, lava flows, cinder cones), a number of mountain ranges (e.g., Providence Mountains, New York Mountains, and parts of the disjunct Clark Mountains), and Cima Dome and Lanfair Valley, which have Joshua tree (*Yucca brevifolia* var. *jaegeriana*) woodlands that have the greatest known abundance of Joshua trees. While most of MOJA is part of the Mojave Desert, elements of the Great Basin and Sonoran deserts can also be found in the preserve at high elevations and along the southern border of the park, respectively. One of the most well-known species on the preserve is the desert tortoise (*Gopherus agassizii*), a species

federally listed as threatened (NPS 2002b). The preserve contains prime habitat for the desert tortoise and approximately half of its lands have been designated Critical Habitat (NPS 2002b).

Grand Canyon-Parashant National Monument (PARA) was established in 2000 through Presidential Proclamation 7265 by President William J. Clinton. It was established to protect "a vast, biologically diverse, impressive landscape encompassing an array of scientific and historic objects." Approximately 424,240 ha (1.048 million ac) of land were set aside for PARA to be cooperatively managed by the BLM and NPS. A majority of the lands for PARA came from land that was managed by BLM (327,287 ha or 808,744 ac) that were part of the Arizona Strip and NPS (84,175 ha or 208,000 ac), generally referred to as the Shivwits Plateau, that were part of LAKE. Each agency retains the primary management authority over their respective sections. There are also a number of Arizona state (9,391 ha; 23,205 acres) and private lands (3,205 ha; 7,920 acres) that are within the park boundary. The entire designated wilderness in PARA, 76,130 ha (188,121 ac), is located on the BLM portion of the park (NPS 2008b).

PARA is located in northwestern Arizona in the drainage of the Colorado River. It is bordered by Grand Canyon National Park to the south and east, LAKE and the state of Nevada to the west, and surrounded by the southern portion of the Colorado Plateau called the Arizona Strip on the north. PARA is isolated from the rest of the Colorado Plateau by the Grand Canyon and even though it borders Grand Canyon National Park, there is no direct access to the canyon from PARA. However, PARA does provide spectacular overviews of the Grand Canyon and major features such as the Shivwits Plateau, Grand Wash Cliffs, and the volcanic Uinkaret Mountains, which include Mount Logan and Mount Trumbull, because of their high elevation, provide distinctive habitats from the surrounding areas. The Monument ranges in elevation from 366 m to 2,447 m.

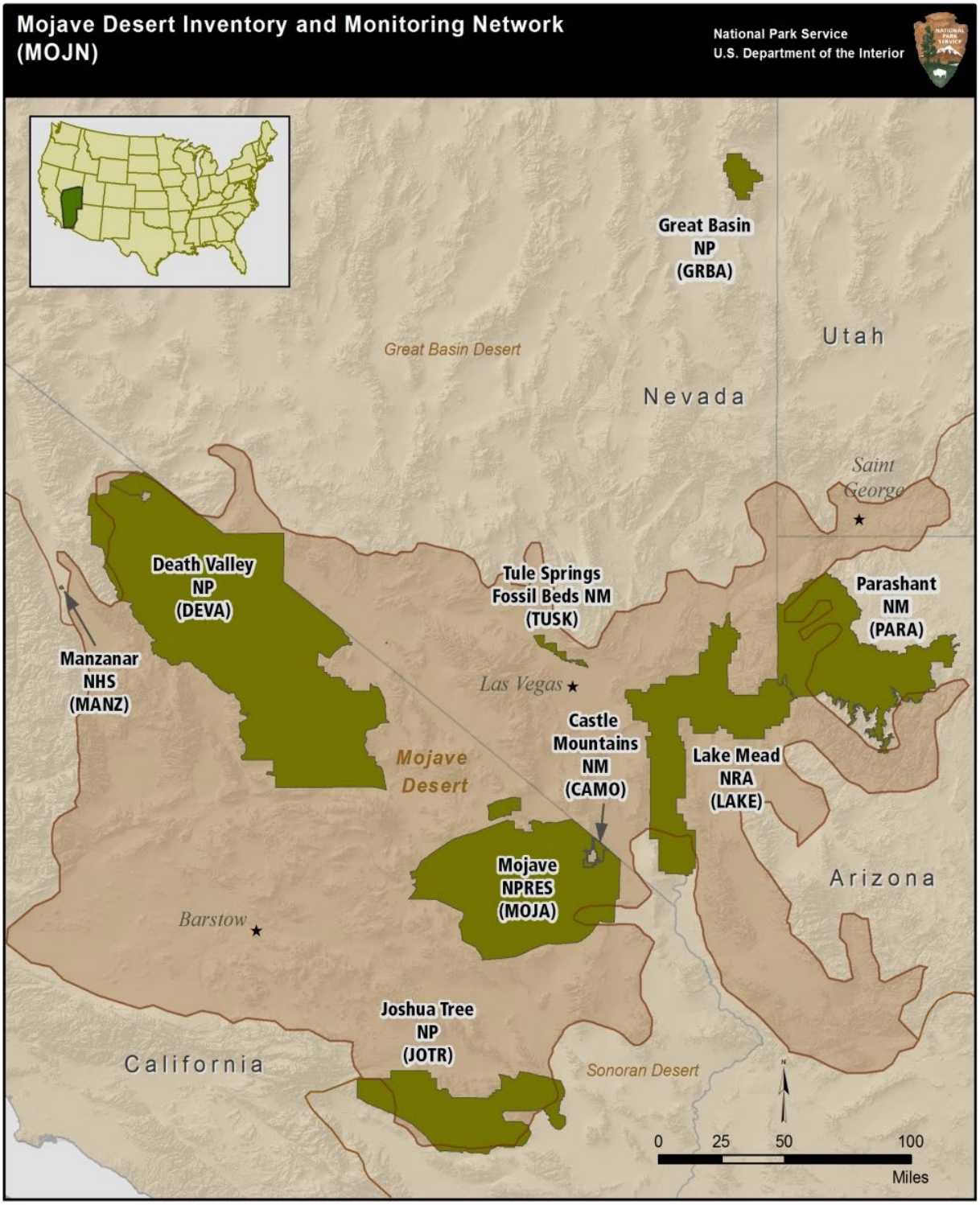


Figure 2. Map of the Mojave Desert Network parks. Note that CAMO is a new park to MOJN that has very recently been added to the network and therefore not included in this plan.

Spring Selection

Vegetation at springs is heavily dependent on the hydrology at the spring and the presence of groundwater, therefore this protocol includes many springs that are currently monitored in the SLS protocol (Moret et al. 2016). These springs were selected by MOJN staff and park personnel for management concerns. The SLS protocol includes springs that are among the highest discharge springs in their parks, important habitats for amphibians, fish, and/or endemic invertebrates. These springs are also particularly important sources of water for wildlife.

Additionally, MOJN and park staff are interested in springs that support a substantial spring vegetation community, contain rare or unique species, and springs that might be at risk of damage or disturbance. The springs monitored under this protocol were selected in consultation with park staff in order to address park management needs (Table 3).

Table 3. Summary of springs monitored by this protocol.

Park	Selected Springs	Number of Springs to Monitor
PARA	Pakoon Springs, Chill Heal Spring* and Tassi Spring	3
JOTR	49 Palms Spring, Smithwater Spring, and Cottonwood Spring	3
DEVA	Mound Spring, Nevares Spring, Saratoga Spring, Texas Spring, and Travertine Spring	5
MOJA	Cornfield Spring *, MC Spring, and Piute Spring *	3
LAKE	Blue Point Spring, Grapevine Spring *, Horsethief Spring*, and Rodgers Spring	4
Total	–	18

*The five springs denoted with an asterisk are included in the DS protocol, but are not included in the SLS protocol (Moret et al. 2016). These additional springs were added to the sample springs because their specific vegetation is of interest to park managers.

Monitoring sites in DEVA

Five springs have been selected for monitoring in DEVA (Table 3): Mound Spring, Nevares Springs, Saratoga Spring, Texas Springs, and Travertine Springs. The locations of these springs are shown in Figure 3.

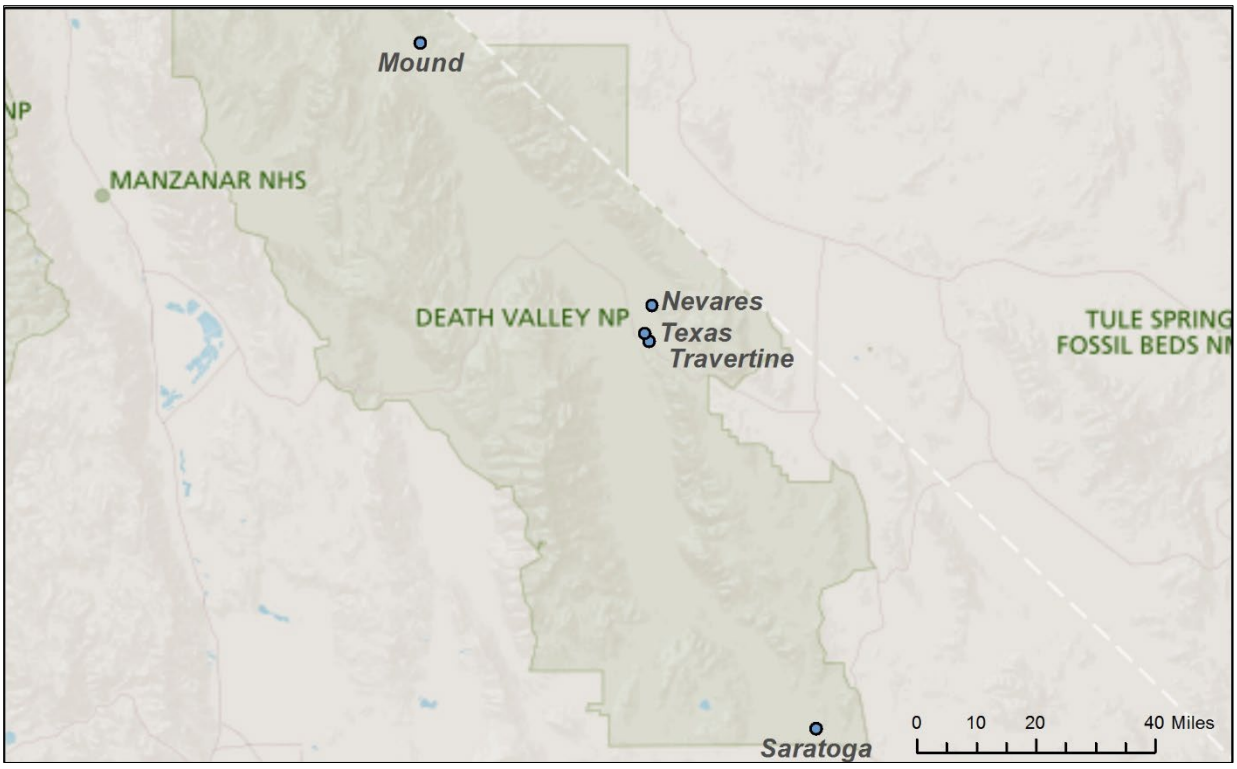


Figure 3. Springs to be monitored at DEVA.

Mound Spring (DEVA_P_MOUN0)

Location and Description: Mound Spring is located in the Grapevine Springs area of the Grapevine Mountains, in the northeastern portion of DEVA. The discrete springs and diffuse discharge areas support approximately 190 acres (77 hectares) of riparian vegetation (Laczniak et al. 2006). This spring has recently been treated for invasive palms (Figure 4). The name of the code includes the name of the park, the letter "p" indicating that it is a perennial spring, and the first four letters of the spring name.



Figure 4. Mound Spring at DEVA in January 2017. Photo by N. Hupp.

Cultural History: Historically, some of the surface water discharge from the Grapevine Springs area was diverted to Scotty's Ranch. In 2008, MOJN and DEVA personnel installed a flume at Mound Spring, one of the highest elevation springs in the area. This outlet was chosen as an index site for the Grapevine Springs area because of its relatively high discharge and the suitability of its source for flume installation.

Flora: Dominant plants at this spring include baccharis (*Baccharis* sp.), arrow weed (*Pluchea sericea*), and sedges. California fan palms (*Washingtonia filifera*) are also present and have been treated with herbicide at this spring, and though most mature individuals are dead, many potentially dangerous trunks remain upright.

Fauna: The area supports populations of two endemic springsnails of the *Tryonia* genus (*T. margae* and *T. rowlandsi*; Hershler et al. 1999) and one springsnail of the *Pyrgulopsis* genus that is more widely distributed (*P. micrococcus*; Hershler and Liu 2008).

Nevares Spring (DEVA_P_NEVA0)

Location and Description: Nevares Springs is located in the Cow Creek residential area of DEVA. The spring emerges in a marshy area on top of a spring mound (Figure 5), and then flows into a wash where it forms a springbrook several hundred m in length. Laczniak et al. (2006) estimate that the spring supports 29 acres (11.7 hectares) of riparian vegetation.



Figure 5. Nevares Spring in DEVA in March 2014. Photo by M. Levandowski.

Cultural History: Until recently, much of the spring's discharge was diverted for park use. In 2014, NPS began evaluating whether a well at the top of the spring mound can be used as the water supply source in place of discharge from the spring. In the spring of 2017, the park conducted a palm removal project to restore native vegetation at the spring.

Flora: According to Sada and Cooper (2012), native herbaceous species such as black bog rush (*Schoenus nigricans*), spikerush (*Eleocharis rostellata*), Cooper's rush (*Juncus cooperi*), bulrush (*Schoenoplectus americanus*), bushy bluestem (*Andropogon glomeratus*), and the native stream orchid (*Epipactis gigantea*) dominate the spring mound, while honey mesquite borders the springbrook on the southern side of the mound. The springs also contain species ranked by California Native Plant Society as rare or having limited distribution, including Death Valley blue eyed grass (*Sisyrinchium funereum*) and Cooper's rush. Mohave thistle (*Cirsium mohavense*) occurs here as well.

Fauna: The springbrook supports populations of the springsnail *Ipnobius robusta* (Hershler and Liu 2008), the Badwater snail (*Assiminea infima*; Sada et al. 2001), and the endemic Nevares Springs Naucorid bug (*Ambrysus funebris*; Whiteman and Sites 2008).

Saratoga Spring (DEVA_P_SARA0)

Location and Description: Saratoga Spring is located near the southern end of DEVA (Figure 3). Saratoga Springs supports approximately 7 hectares of wetlands vegetation (primarily reeds and bulrushes) and open water. At the southern end of the spring, water flows from a historic spring box to a source pool that is approximately 10 m in diameter. From the source pool, water flows north along a low-banked channel through the reeds to a series of artificial downstream ponds (Figure 6), the largest of which is approximately 60 m by 200 meters.



Figure 6. Saratoga Spring at DEVA in January 2017. Photo by N. Hupp.

Cultural History: Throughout its history, the spring has been used as a watering stop for mule teams, the water supply for nearby mines, the source for a water bottling operation, and a tourist spa (Latschar 1981), so the area has been highly disturbed.

Flora: The mosaic of marsh vegetation is dominated by patches of common reed (*Phragmites australis*), saltgrass (*Distichlis spicata*), and bulrush.

Fauna: Saratoga Springs supports the endemic Saratoga Springs pupfish (*Cyprinodon nevadensis nevadensis*), the endemic Saratoga Springs belostoman bug (*Belostoma saratogae*), and three springsnail species: *Pyrgulopsis amargosae*, an unidentified species of the genus *Pyrgulopsis*, and *Tryonia variegeta* (Hershler and Liu 2008, Hershler et al. 1999). Saratoga also provides important migratory bird habitat (Mojave Desert Ecoregional Planning Team 2001).

Texas Spring (DEVA_P_TEXA0)

Location and Description: Texas Springs (Figure 7) is located in the Furnace Creek area of DEVA. Currently, the discharge from the historic collection system is released to the ground surface via a pipe, where it forms a small pool. This water flows into a spring brook that runs for roughly 200 m before flowing into a narrow, deeply-incised ravine up to 5 m deep (Figure 7). Laczniak et al. (2006) estimate that the spring supports 11 acres (4.5 hectares) of riparian vegetation.



Figure 7. Riparian area and incised ravine below Texas Spring flume box in DEVA in March 2008. Photo by C. Caudill.

Cultural History: Discharge from Texas Spring was diverted sometime before 1941 to provide water to the U.S. Borax and Chemical Corporation. Subsequently, Texas Spring provided water to the Texas Springs Campground and to a 2 million gallon storage tank that served as a potable water supply for the Furnace Creek area. The collection galleries, French drains, and tunnel used to collect spring discharge left the spring ecosystem highly disturbed. The diversion is estimated to have reduced the historic springbrook length by 85% (Threloff and Koenig 1999). While no records are available, the morphology of the ravine suggests that it was formed by the release of water from the collection system onto the hill slope.

Flora: Dominant species here include honey mesquite (*Prosopis glandulosa var. torreyana*), baccharis, cattail (*Typha* sp.), and desert holly (*Atriplex hymenelytra*).

Fauna: The spring supports the Amargosa Naucorid (*Pelocoris shoshone amargosus*) and a population of springsnails (*Tryonia robusta*).

Travertine Spring (DEVA_P_TRAV0)

Location and Description: Travertine Springs is located in the Furnace Creek area of DEVA, east of Highway 190. Travertine Springs includes at least 10 spring outlets scattered over an area of about 35 hectares (Sada and Cooper 2012). There are two outlets, Travertine 1 and Travertine 2, which flow in well-defined springbrooks. Travertine 1 flows from a pipe (part of a former collection system) on top of a spring mound. The spring flows through a narrow channel down the flank of the spring mound into a wash below. Once in the wash, the spring flows for several hundred m until it is diverted into a concrete drain on the shoulder of Furnace Creek Road. Travertine 2 flows from a pipe near the head of a wash several hundred m to the west of Travertine 1. Currently, the springbrook extends for

several hundred meters. Laczniak et al. (2006) estimate that the spring supports 21 acres (8.5 hectares) of riparian vegetation; although the spring's riparian vegetation has changed greatly since those data were collected.

Cultural History: Until recently, the NPS diverted much of Travertine Springs discharge for use within the park, including diversions to Xanterra Parks and Resorts and the Timbisha Shoshone tribe. As of 2014, rehabilitation is ongoing. Woody vegetation at the spring was consumed by fire in August 2010, and all remaining palms were mechanically removed in February 2011 (Sada and Cooper 2012). The riparian corridor has been restored with native vegetation (Figure 8).



Figure 8. Travertine Springs in March 2015. Photo by C. Matesich.

Flora: Dominant species at the springs include saltgrass, arrow weed, and desert baccharis (*Baccharis sergiloides*) where groundwater depth is between 1 m and 3 m, spikerush, bulrush, Cooper's rush, hot springs fimbristylis (*Fimbristylis thermalis*), and cattail where groundwater discharges to the surface, and both honey and screwbean mesquite where deeper water tables occur (Sada and Cooper 2012). In addition, the springs contain several species ranked by the California Native Plant Society as rare or having limited distribution, including the aforementioned hot springs fimbristylis and Cooper's rush, as well as California sawgrass (*Cladium californicum*), black bog rush, Death Valley blue eyed grass, and other rare species (Mojave Desert Ecoregional Planning Team 2001). Several invasives are also present, including rabbitsfoot grass (*Polypogon monspeliensis*), *Tamarix* sp., Bermuda grass (*Cynodon dactylon*), and some young palms.

Fauna: The spring supports populations of the springsnail *Ipnobius robusta* (Hershler and Liu 2008), the Nevares Springs Naucorid bug (Sada and Cooper 2012), and the Badwater snail (Sada et al. 2001).

Monitoring sites in JOTR

Three springs have been selected for monitoring in JOTR (Table 3): Cottonwood, Fortynine Palms, and Smith Water Canyon. The locations of these springs are shown in Figure 9.

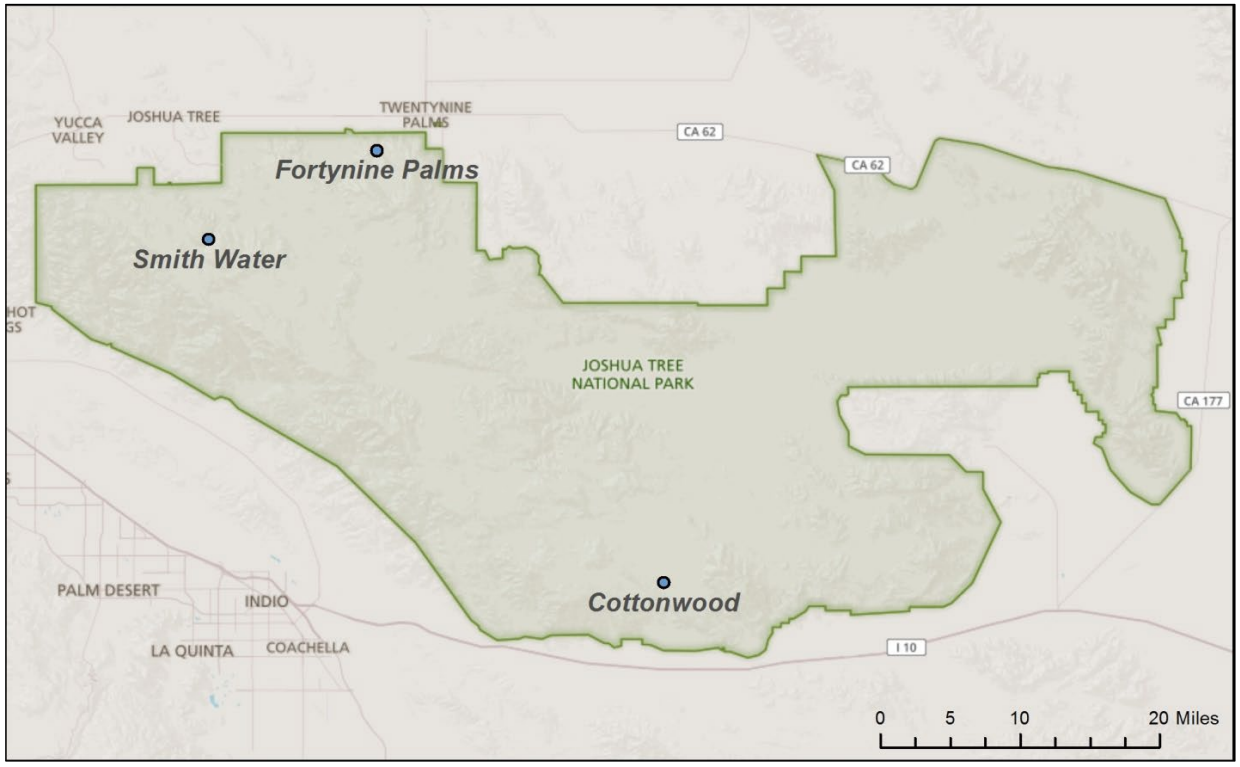


Figure 9. Springs to be monitored at JOTR.

Cottonwood Spring (JOTR_P_COT0235)

Location and description: The spring is located near the southern entrance of JOTR. It is characterized by large boulders shading a ravine with riparian vegetation (Figure 10).



Figure 10. Cottonwood Spring in JOTR in November 2016. Photo by MOJN Field Crew.

Cultural History: There is a popular trailhead at this spring (NPS 1999b).

Flora: Desert almond (*Prunus fasciculata*) grows near the spring, and there are fan palms dating to the 1920s (NPS 1999b).

Fortynine Palms (JOTR_P_FORT0)

Location and Description: Fortynine Palms Oasis is a fan-palm oasis located at the confluence of two washes near the Park's northern boundary. The oasis consists of approximately 1 hectare of dense riparian vegetation, principally fan palms and willows (Figure 11). Surface water is present year round in pools below the palms.



Figure 11. Fortynine Palms Oasis in JOTR in July 2014. Photo by MOJN Field Crew.

Cultural History: Although the oasis was used as a water source by European Americans, any diversion structures they may have installed have been washed out. The oasis is scoured by major storms every few years. The United States Geological Survey (USGS) monitored discharge in the wash below the oasis from 1963 to 1971 and found that, while wash was dry for all but a few days of the year, more than 100 acre-feet (123,300 cubic meters) of water could pass through it in a single storm event (Nishikawa et al. 2004). The USGS attempted to monitor water levels in the oasis pools in 2005 and 2006, and had their equipment destroyed by a storm (Schroeder et al. 2015). Each time the oasis is scoured, the positions and depths of the pools can change. The frequent changes in the pools present a challenge for long-term monitoring.

Flora: Dominant plants include California fan palm, willow (*Salix* sp.), cattail, sedge (*Carex* sp.), and false lily of the valley (*Maianthemum* sp.).

Fauna: The oasis is a major water source for desert bighorn sheep in the park (e.g., Douglas 1976, Longshore et al. 2009) and is the destination for a popular day hike. Red-spotted toads (*Bufo punctatus*) and California treefrogs (*Pseudacris cadaverina*) have been observed in the oasis (Schroeder et al. 2015). The spring also hosts riparian bird species (Mojave Desert Ecoregional Planning Team 2001).

Smith Water Canyon Spring (JOTR_P_SMIT0)

Location and Description: Smith Water Canyon Spring is located in Smith Water Canyon, a steep, narrow canyon that descends approximately 1,500 feet (457 meters) in elevation from Covington Wash to Quail Wash. The spring emerges from boulders at the base of an ephemeral waterfall, and flows through several natural bedrock depressions (Figure 12).



Figure 12. Smith Water Canyon Springs, September 2017. Photo by MOJN Field Crew.

Cultural History: There is no evidence of human manipulation of the spring system.

Flora: Vegetation is dominated by baccharis and willow. Non-native sow thistle (*Sonchus* sp.) is also present.

Fauna: Smith Water Canyon is an important water source for desert bighorn sheep. Mountain lions (*Puma concolor*) have also been observed in the canyon.

Monitoring sites in LAKE

Four springs have been selected for monitoring in LAKE (Table 3): Blue Point Spring, Grapevine Spring (AZ), Horsethief Canyon Spring, and Rogers Spring. The locations of these springs are shown in Figure 13.

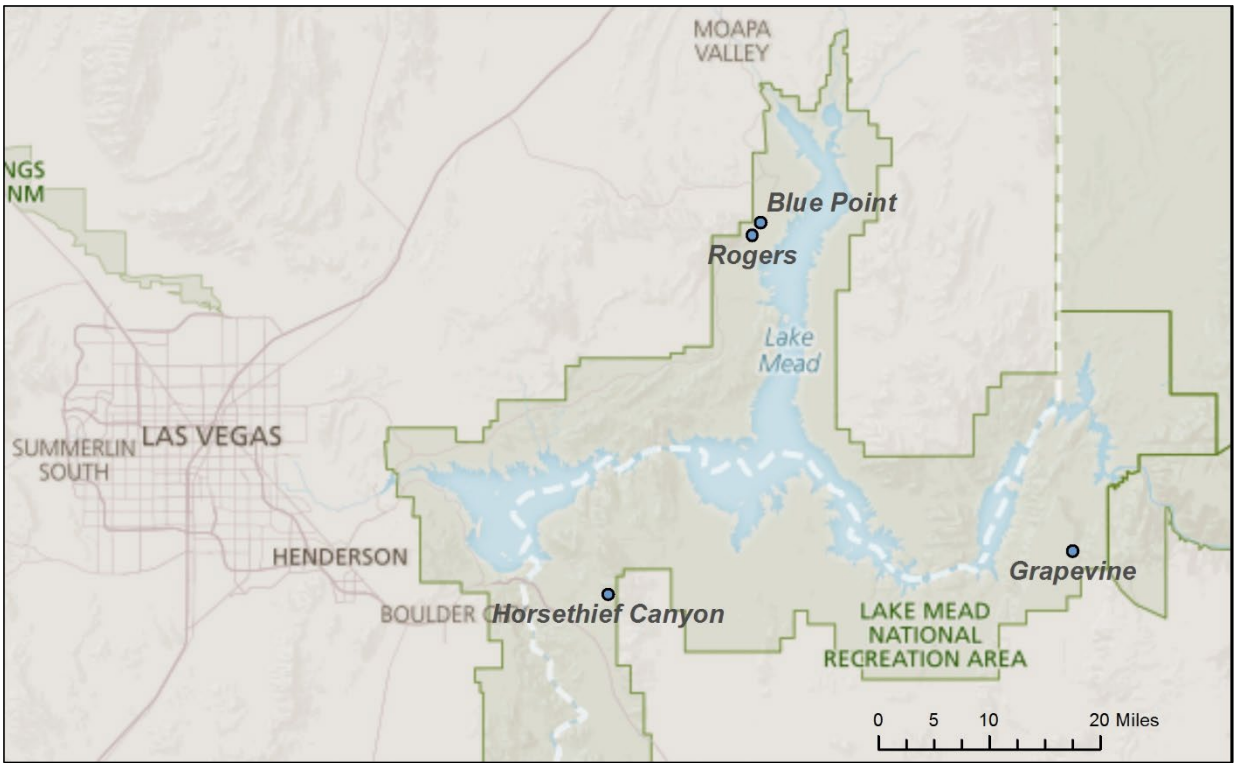


Figure 13. Springs to be monitored at LAKE.

Blue Point Spring (LAKE_P_BLUE0)

Location and Description: Blue Point Spring consists of a pool that spills into a springbrook hundreds of m long (Figure 14).



Figure 14. Blue Point Spring in LAKE in February 2012. The weir is visible in the top left. Photo by MOJN Field Crew.

Cultural History: The pool and the springbrook are separated by a weir (a dam that controls the pool level).

Flora: Blue Point Spring is characterized by dense emergent vegetation, including sedges, as well as yerba mansa (*Anemopsis californica*), goldenrod (*Solidago* sp.), willow, and mesquite.

Fauna: The spring hosts three species of snails (*Assimenea* sp., *Pyrgulopsis coloradensis*, and *Tryonia* sp.) in different habitat niches (D. Sada personal communication). It also hosts an invasive snail species and invasive fish. Blue Point Spring is the location of one of a handful of extant natural populations of relict leopard frog (*Rana onca*). The vegetation at this spring is at times under active management to provide habitat for the relict leopard frog (Jaeger and Rivera 2015).

Grapevine Spring (LAKE_P_GRA0058)

Location and Description: Grapevine Spring is located near Meadview, Arizona in LAKE. Canyon walls encase this spring and create a sharp transition from riparian vegetation to upland vegetation. This spring has significant amounts of surface water and two comparably deep pools. Pools at Grapevine Spring are connected my small flowing spring brooks. The water cascade at the top of one pool is an uncommon feature in MOJN parks (Figure 15).



Figure 15. Grapevine Spring (AZ) in LAKE in December 2017. Photo by N. Hupp.

Cultural History: Inactive flow modification is present downstream from the source pool which indicates past cattle ranching at the spring. The spring has a semi-maintained social trail leading to the waterfall and source pool and signs of other human disturbance, such as graffiti.

Flora: The dominant plants found at Grapevine Spring include grapevine (*Vitus* sp.), cattail, desert willow (*Chilopsis* sp.), and reeds (*Phragmites* sp.) Invasive plants present at the spring include red brome.

Fauna: Aquatic invertebrates and amphibians have been observed by DS Field Crews.

Horsethief Canyon Spring (LAKE_P_HOR0042)

Location and Description: This spring is located in Arizona south of Lake Mead. It has a 4x4 road within 1 mile and is accessed with an informal hiking trail (Figure 16).



Figure 16. Horsethief Canyon Spring in LAKE December 2017.

Cultural History: There is no evidence of human manipulation of the spring system.

Flora: Horsethief canyon has riparian species such as saltgrass, baccharis, and cattail. Additionally, the invasive plant *Tamarix* sp. is present at the spring.

Fauna: Large mammal bones, from either a sheep or deer, have been found at Horsethief Canyon during DS field visits.

Rogers Spring (LAKE_P_ROGE0)

Location and Description: Rogers Spring consists of a 25 meter by 25 meter concrete bathing pool (Figure 17). Water spills from the pool into a springbrook hundreds of m long. This location is a popular travel stop for visitors to LAKE, and it has a parking lot, picnic tables, and other infrastructure.



Figure 17. Rogers Spring at LAKE in January 2017. Photo by N. Hupp.

Cultural History: Rogers Spring has been highly disturbed by human use, in particular by the construction of the bathing pool by the Civilian Conservation Corps in the 1930s.

Flora: Dominant plants include arrow weed, sedges, and saltgrass. Invasive plants present at the spring include date palm (*Phoenix dactylifera*) and *Tamarix* sp. There is dense vegetation encroaching upon the open area of the stream as of 2014 (Jaeger and Rivera 2015).

Fauna: The aquatic ecology of the pool is dominated by aquarium fish and turtles released by park visitors. The springbrook is the location of one of a handful of extant natural populations of relict leopard frog.

Monitoring sites in MOJA

Three springs have been selected for monitoring in MOJA (Table 3): Cornfield, MC, and Paiute. The locations of these springs are shown in Figure 18.

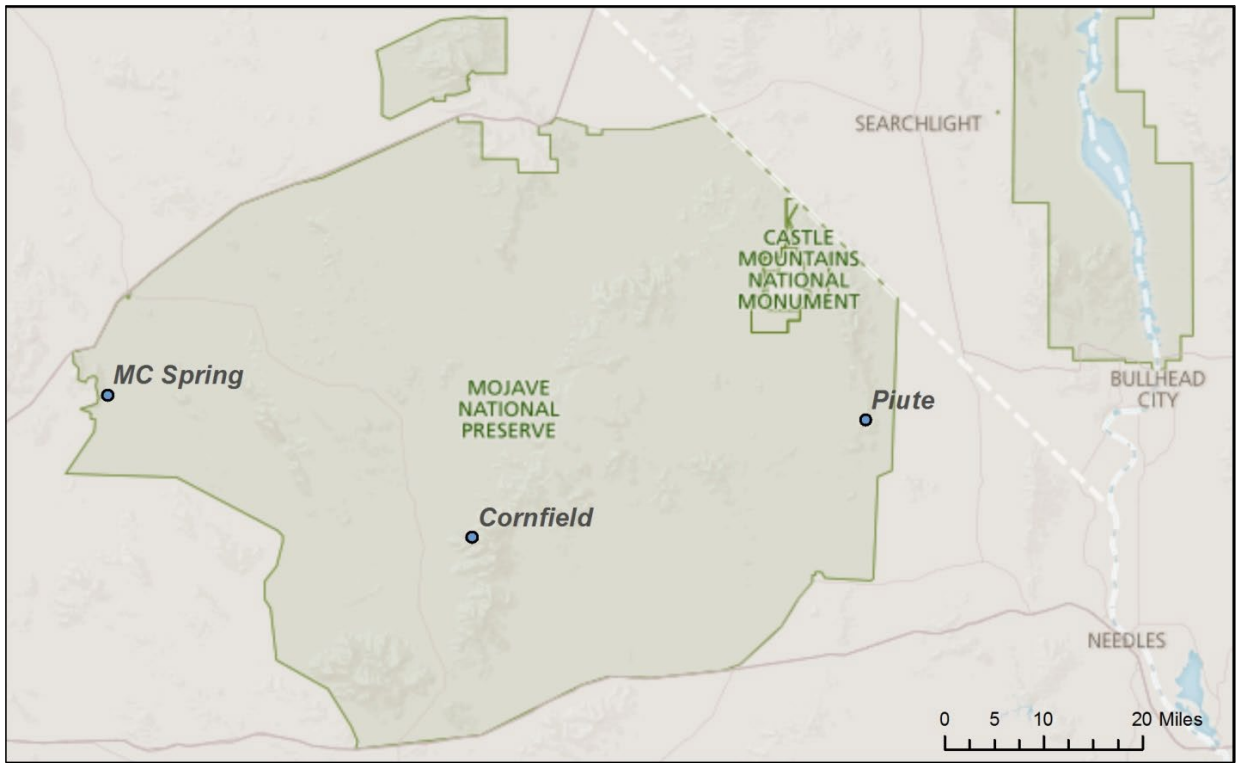


Figure 18. Springs to be monitored at MOJA.

Cornfield Spring (MOJA_P_COR0060)

Location and Description: Cornfield Spring is a rheocrene spring located on the western flank of the Providence Mountains, and it is the source of one of only two perennial streams found within the Preserve (Persons and Nowak 2007). According to Hazard and Rotenberry (1996), the spring is 3 m wide and runs through a canyon, with the stream eventually widening to 20-50 meters. Water surfaces in a cement and rock diversion structure, and the NPS classifies this spring as "highly disturbed" (NPS 2002b; Figure 19).



Figure 19. Diversion structure at Cornfield Spring. Photo by MOJN Field Crew.

Cultural History: A mine entrance is located near the spring source. Mining began in the Providence Mountains in 1863. The Cornfield Springs Consolidated Mine was likely too small for commercial operation and was mapped by the USGS in an "area with low mineral resource potential" (Goldfarb et al. 1983).

Flora: Dominant native shrubs at the spring include creosote and catclaw acacia, and other common species include skeletonweed (*Eriogonum deflexum*), rabbitbrush (*Chrysothamnus nauseosus*), goldeneye (*Bahiopsis parishii*), desert baccharis, and invasive red brome (Hazard and Rotenberry 1996). Records indicate that ferns are also present at this spring (NPS 2002b).

Fauna: Scientists from the USGS found shell remains from federally listed desert tortoise at the spring in during their surveys in 2004-2005, as well as an abundance of red-spotted toads (Persons and Nowak 2007). Cornfield Spring is also one of three springs in the eastern Mojave Desert identified as an Important Bird Area by the Audubon Society.

MC Spring (MOJA_P_MCSP0)

Location and Description: MC Spring is located at Zzyzx, a former resort and spa currently operated as a research center. There are a number of springs near Zzyzx, and they are sometimes collectively referred to as Zzyzx Springs or Soda Springs. MC Spring is a small, limnocrene spring with no outlet (Figure 20). Vegetation is removed as needed to maintain the pond as an open-water fish habitat.



Figure 20. MC Spring in MOJA in November 2017. Photo by N. Hupp.

Cultural History: The springs at Zzyzx were used for a variety of purposes in the 19th and 20th centuries (Woo and Hughson 2003), but there is no evidence of direct diversion from MC Spring. However, as Woo and Hughson (2003) state:

"The fact that cattails and sedges in MC Spring must be cut back about every 18 months or so suggests that the existence of this open pool of water, with a surface area of 250 square feet [23.2 square meters] and a volume of 1,000 cubic feet [28.3 cubic meters], is anthropogenic."

Flora: Dominant native vegetation includes cattail (*Typha domingensis*), reed grass, rushes, bulrush, yerba mansa, borax weed (*Nitrophila occidentalis*), and saltgrass. Tamarisk, date palm, and California fan palm were introduced near MC Spring at Zzyzx as nursery stock when the center was operated as a spa. Vegetation appears to be actively managed at the spring as it is reported that Zzyzx staff removes vegetation on a yearly basis (Barthel 2008).

Fauna: MC Spring gets its name from the Mohave tui chub (*Siphateles bicolor mohavensis*), a federally-listed endangered desert fish species. The Mohave tui chub was extirpated from the Mojave River in the 1960s, and MC Spring is one of its last remaining natural habitats (Henkanaththegedara and Stockwell 2011). The spring is also an important water source for desert bighorn sheep.

Piute Spring (MOJA_P_PIU0161)

Location and Description: Piute Spring is a rheocrene spring surrounded by dense vegetation, feeding a perennial stream and riparian corridor through a canyon dominated by tree and shrub species (Figure 21; NPS 2002b). It is located in the Piute Mountains Wilderness Area.



Figure 21. Piute Springs in MOJA in November 2017. Photo by N. Hupp.

Cultural History: Piute Spring is a held as a sacred site for many of the tribes in the Mojave Desert, including Twenty-Nine Palms Band of Mission Indians, Colorado River Indian Tribes, Chemehuevi Indian Tribe, and Fort Mohave Indian Tribe. This spring is located on the old Mojave Government Road and is known to have "prehistoric and extensive historic use, including farming" (NPS 2002b). The ruins of Fort Piute stand nearby, with an interpretive site and hiking trails. Many of the most mature trees burned in a fire in 2004, dramatically altering community structure and composition (Persons and Nowak 2007).

Flora: Hazard and Rotenberry (1996) observed willow (*Salix gooddingii* and *S. exigua*), desert willow (*Chilopsis linearis*), and *Tamarix* sp. dominating the vegetation at Piute Spring (though the *Tamarix* sp. has since been largely removed) and determined the shrubby understory had 40-90% canopy cover. Other dominant plants include Fremont cottonwood, cattail, sedges, and baccharis (*Baccharis salicifolius*).

Fauna: The spring is an important water source for desert bighorn sheep. Red-spotted toads are also inhabitants of the spring, and biologists with the USGS observed several malformed individuals following the fire in 2004 (Persons and Nowak 2007).

Monitoring sites in PARA

Three springs have been selected for monitoring in PARA (Table 3): Chill Heal Spring, Pakoon Springs, and Tassi Spring. The locations of these springs are shown in Figure 22.

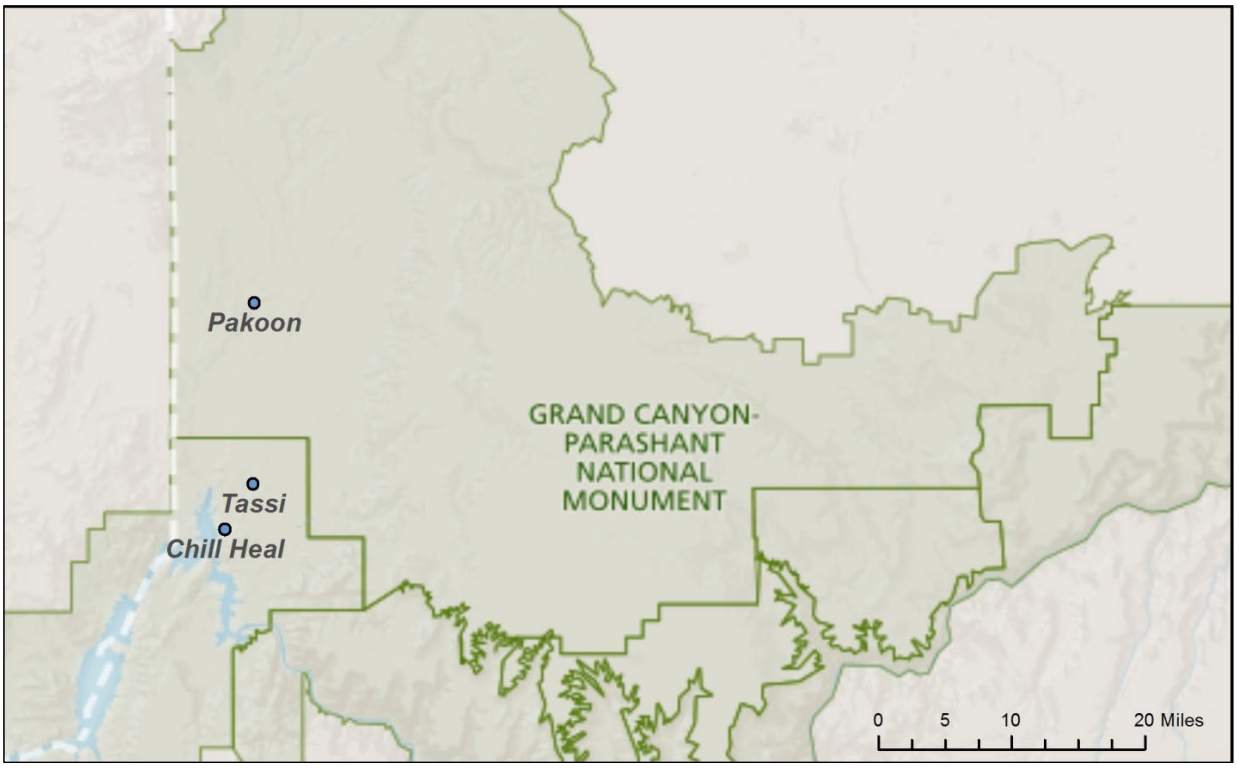


Figure 22. Springs to be monitored at PARA.

Chill Heal Spring (PARA_P_CHI0190)

Location and Description: Chill Heal Spring is a cool spring located in a steep canyon near the northeastern shore of Lake Mead, in the Grand Wash (Figure 23).

Cultural History: Chill Heal has moderate impacts from cattle (Jaeger and Rivera 2015).

Flora: Arrow weed, Arizona grape (*Vitis arizonica*), native thistle species, and sedges grow in abundance at the spring, along with non-native red brome (Figure 23).

Fauna: University of Nevada Las Vegas personnel visited the springs in 2009 to assess their potential as a relict leopard frog translocation site and observed canyon tree frogs (*Hyla arenicolor*) and unidentified tadpoles in the stream course. Springsnails were also detected in the lower portion of the spring during this visit (Jaeger and Rivera 2015).



Figure 23. Arrow weed growing at Chill Heal Spring in May 2017. Photo by N. Hupp.

Pakoon Springs (PARA_P_PAKO0)

Location and Description: Pakoon Springs currently consist of a large (~1 hectare) marshy area consisting of several "arenas" with small outflows, a reed-dominated pool (Figure 24), and a riparian corridor in the wash bottom approximately 1 km long.



Figure 24. Source of Pakoon Springs in PARA in in October 2016. Photo by N. Hupp.

Cultural History: The entire discharge of Pakoon Springs was used for agriculture until the 1980s. All spring outflows were diverted to a reservoir behind a dam, and from there to an irrigation system. An extensive restoration program was initiated in 2006 to restore biodiversity and ecological function (BLM 2007). Restoration included extensive re-grading, diversion of flow from the reservoir into a nearby wash, establishment of a riparian corridor in that wash, excavation and removal of all diversion structures, eradication of invasive species, and re-establishment of wetlands at outflows (Burke et al. 2015). Further restoration work in spring of 2015 included removal of the pool and recontouring of the surrounding area (Figure 24).

Flora: Dominant native plants at Pakoon Springs include Gooding's willow (*Salix goodingii*), bulrush, and cattail. *Tamarix* sp. and date palm were removed as part of the restoration program and are currently managed along with Russian thistle (*Salsola* sp.), Malta star-thistle (*Centaurea melitensis*), Bermuda grass, cheat grass, and other species (Fox 2016). As of 2016, no listed species had been detected at the springs (Fox 2016).

Fauna: The native Woodhouse's toad (*Bufo woodhousii*) and the non-native bullfrog (*Rana catesbiana*) are found in Pakoon Springs. Arizona Game and Fish is actively attempting to eradicate bullfrogs from the spring.

Tassi Spring (PARA_P_TASS0)

Location and Description: Tassi Spring is located on the historic Tassi Ranch, one the most important cultural resources in PARA. Water seeps from many locations in the ranch area, but the only discrete spring outlet with flowing water is the one that flows into an irrigation canal on the hill slope behind the ranch buildings (Figure 25).



Figure 25. Site overview of Tassi Spring in PARA in October 2016. Photo by N. Hupp.

Cultural History: All of Tassi Spring's outlets were diverted during the era that the ranch was in use (1936-1996), and these diversions still control the spring today. The spring's vegetation is actively managed, both to preserve the irrigation canal as a cultural resource and to provide aquatic habitat.

Flora: Dominant native shrubs surrounding the spring include thickets of arrow weed, Gooding's willow, catclaw acacia, and mesquite (*Prosopis* spp.). Fremont cottonwood is also present, though they were originally planted as a windbreak for ranching activities (NPS 2010a).

Fauna: Tassi Spring contains the only native fish in PARA, the speckled dace (*Rhinichthys osculus*). The irrigation canal contains a population of Grand Wash springsnails (*Pyrgulopsis bacchus*; Sada 2005) that are endemic to a small number of springs in the Grand Wash drainage. The spring is also being used as a refugium for the relict leopard frog.

Current Management Efforts and Other Vital Signs Monitoring

Desert spring vegetation is heavily dependent on hydrologic elements at the spring. Due to limited resources and staff constraints, this protocol only focuses on desert spring vegetation. However, because of this strong relationship between water and vegetation, we will implement this protocol at springs that are currently monitored in detail in a separate protocol implemented at MOJN, the SLS (there are five springs that are exceptions; Moret et al. 2016). The SLS is a hydrology protocol that addresses three MOJN vital signs, Surface Water Dynamics, Surface Water Chemistry, and Groundwater Dynamics and Chemistry, in springs that have been selected as high priorities for monitoring. The SLS protocol monitors spring discharge, spring water chemistry and quality, and benthic macroinvertebrate and springsnail communities at springs of interest. The springs monitored under SLS protocol were selected in consultation with park staff in order to address park management needs. MOJN staff and park managers chose springs that are:

1. among the highest discharge springs in their parks
2. important habitats for amphibians, fish, and/or endemic invertebrates
3. important sources of water for wildlife

This spring vegetation monitoring protocol is implemented at all springs included in the SLS protocol and at five additional springs. Our spring vegetation data builds off the SLS water quality data to give a more complete understanding of both the biotic and abiotic components of desert springs. By co-locating the sampling locations of these two protocols, we maximize our efforts. While understanding vegetation community dynamics is interesting on its own, vegetation, particularly at desert springs, is closely linked to water dynamics. Viewing these data together allows for a more complete understanding of the entire springs. Data collected at overlapping SLS and SV springs are shown in Table 4.

Table 4. Summary of data collected by the SLS Protocol.

Park	Spring	Water Quality	Discharge Measurement Method	Discharge Measurement Frequency	Number of Biennial BMI Samples	Biennial Springsnail Monitoring
DEVA	Saratoga	Biennial	Pool stage1	Continuous	4	Yes
	Texas	Biennial	Flume1	Continuous	2	Yes
	Travertine	Biennial	Flume, flowmeter1	Continuous	3	Yes
	Nevares	Biennial	Flume, flowmeter1	Continuous	2	Yes
	Mound	Biennial	Flume1	Continuous	1	Yes
JOTR	49 Palms	Quarterly	Pool area	Quarterly	1	Yes
	Smith Water Canyon	Quarterly	Springbrook length	Quarterly	1	Yes
LAKE	Blue Point	Quarterly	Weir	Continuous	2	Yes
	Rogers	Quarterly	Flume2	Continuous	0	No
MOJA	MC	Quarterly	Pool stage	Continuous	0	No
PARA	Pakoon	Quarterly	Flume1	Continuous	3	Yes
	Tassi	Quarterly	Volumetric of portable flume	Quarterly	1	Yes

[1] Measurements made by DEVA staff, data analyzed by WRD.

[2] Measurements and data analysis by USGS.

Additionally, this protocol complements the Invasive Plant Species Early Detection Monitoring Plan (IPSED; Hupp et al. 2017) to document the occurrence of invasive plant species at springs. The IPSED plan delineates methods to search for and record invasive plant species in a way that are quickly reported to parks and invasive species managers to ensure a timely response for treatment if necessary.

Project Goal and Monitoring Questions

The purpose of this monitoring project is to gather baseline data about desert spring vegetation - a MOJN vital sign - and document changes in community composition in the Mojave Desert (Chung-MacCoubrey et al. 2008). To achieve these goals, this protocol monitors status and trends in the structure and dynamics of the spring vegetation in select springs of MOJN parks to provide scientifically sound data for management decisions affecting spring systems. Monitoring objectives for the vital signs are presented in the form of *monitoring questions* that identify conceptual and management issues and *monitoring objectives* that link monitoring questions to data collection. Monitoring questions and objectives for MOJN were originally identified through the 2004 Network-Level Vital Signs Scoping Workshop (Chung-MacCoubrey et al. 2008) and have been revised here to address the newer concerns of the MOJN parks.

Monitoring questions:

1. What are the status and trends in plant community composition and species richness at select desert springs in MOJN?

2. How is species diversity and richness associated with human-related and natural disturbances?

Long-term Monitoring Objectives

To address the monitoring questions above, this protocol's objectives are to:

- Determine status and long-term trends in plant species composition and richness (e.g. percent cover, number of different species) in selected springs of management concern in MOJN parks ("status and trends of community").

- Determine status and long-term trends in the distribution and abundance (e.g. plant cover, number of plants) of target invasive plant species at selected springs in MOJN parks ("status and trends of invaders").

- Determine status and long-term trends in the distribution and abundance (e.g. canopy cover, tree size) of selected overstory tree species of special management interest at selected springs in MOJN parks ("status and trends of overstory").

- Determine status and long-term trends of natural and anthropogenic disturbances, measured by the percentage of the site impacted by some activity (e.g. grazing, recreational vehicles, human disturbance) at selected springs in MOJN parks ("status and trends of disturbance").

Sampling Design

Rationale for Sampling Design

This sampling design development considered many sampling trade-offs, and our decisions reflect a consideration of our objectives to detect both the status and trends in the desert spring vegetation community, and the amount of effort associated with the sampling design. We placed a premium on obtaining substantial information from large, intensively measured, permanent plots, and accepted the limits to sample size, spatial extent, and the scope of inference that necessarily come from this design. Peet et al. (1998) identified additional sampling design decision criteria that we subscribe to, including one of open architecture, involving a design that can be easily added to or modified without compromising the utility of earlier data. We think this approach is particularly important for long-term studies subject to unanticipated future uses and modifications and is critical to accommodate the needs and constraints of multiple parks and networks involved in this particular protocol. Transects will be permanently marked (and if permanently marking is not possible, heavily documented so they can be accurately revisited) so they can be directly compared over time and have more statistical power for detecting change (Elzinga et al. 2001).

Target Communities, Sampling Frames, and Location of Plots

The targeted vegetation communities addressed in this protocol are spring vegetation communities at specific perennial springs in MOJN. This protocol is not designed to compare across springs statistically. The springs included in this protocol differ in terms of total area, community composition, geographic features, and amounts of perennial water, therefore an unfeasibly large sample of springs would be required to control for the inter-spring variation; this protocol accepts this tradeoff due to resource constraints. The data collected here compare vegetation over time within a spring (i.e., the inference population). We can broadly discuss differences over time across springs, but statistical conclusions are neither intended nor advised.

Among these sites, each spring is unique in terms of hydrology and vegetation; standardizing a method to apply across these locations is challenging (and likely a reason that long-term monitoring of desert springs is rare). For purposes of application, we have grouped springs into two different classes in terms of their hydrology and vegetation, rheocrene and limnocrene springs. Rheocrene springs are a pool or series of pools that flow downslope into streams, referred to as “stream dominated.” Limnocrene springs consist of standing water or wetlands but do not terminate in streams, referred to here as “pool dominated.”

Stream Dominated (Rheocrene) Springs

These springs are usually longer than they are wide. These types of springs emerge in canyon or wash locations where the spring vegetation is found in the lowest parts of canyons, often with steep walls. While they may have a pool at the top, the main feature of these springs is the stream that flows downstream (Figure 26). There are 14 springs that fall into this category (Table 5).

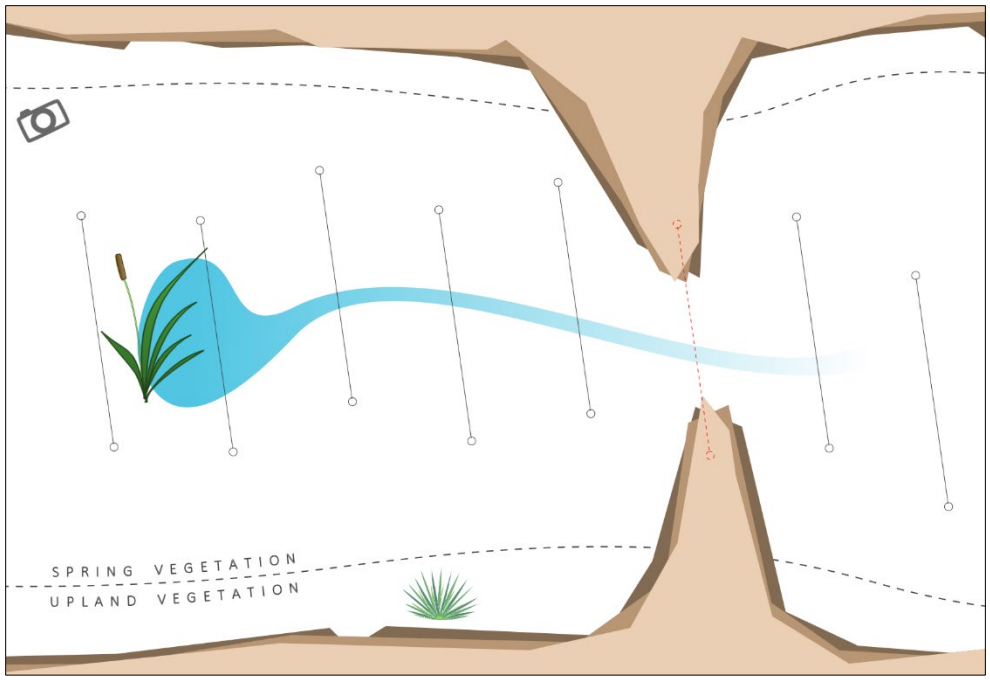


Figure 26. Example layout of transects and photo point for rheocrene springs.

Table 5. Springs in this protocol are grouped into two classes for sampling design purposes, stream dominated, and pool dominated.

Park	Stream Dominated (Rheocrene)	Pool Dominated (Limnocrene)
PARA	Tassi, Chill Heal*	Pakoon
JOTR	49 Palms, Smithwater, Cottonwood	–
DEVA	Nevares, Travertine, Texas, Mound	Saratoga
MOJA	Piute*, Cornfield*	MC
LAKE	Blue Point, Rodgers, Grapevine*, Horsethief*	–

*All springs are also included in the SLS protocol (Moret et al. 2016), except five springs denoted with an asterisk.

Pool Dominated (Limnocrene) Springs

These spring vegetation areas are often wider than they are long. These springs are usually in basins or flat locations where surface water remains in standing pools or creates wetlands (Figure 27). There are four springs in this category (Table 5).

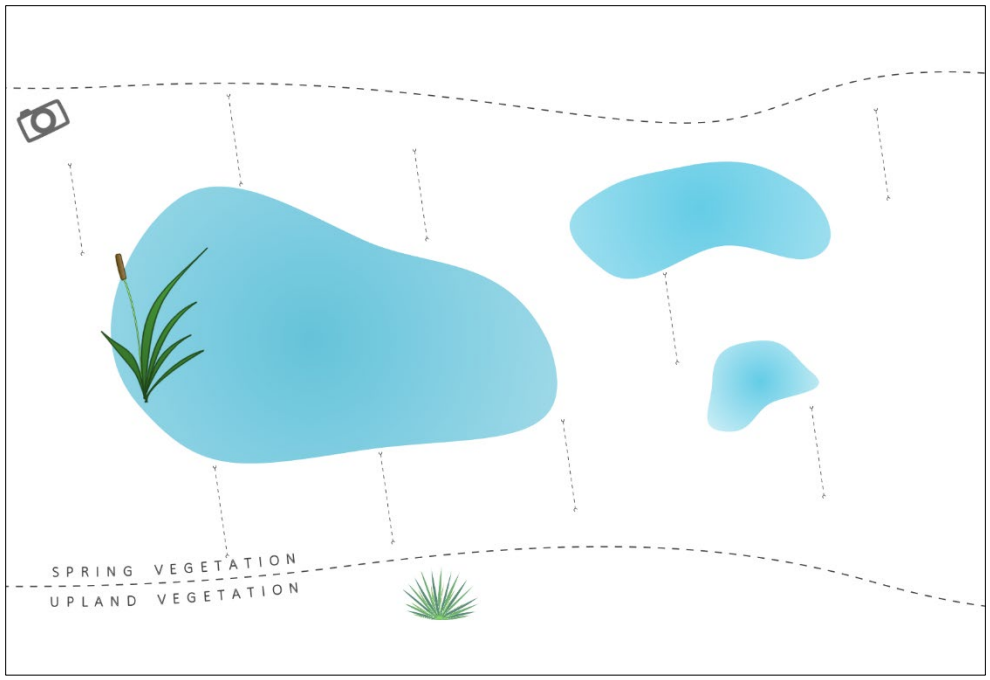


Figure 27. Example layout of transects and photo point for limnocrene springs.

Sampling Frequency and Timing

MOJN crews will sample desert spring vegetation one week per park every three years (Table 6). After the locations are established, Field Crews can sample one spring per day during the field season. This schedule will allow for weather or other delays, and each park scheduled for sampling can likely be completed in one week.

Table 6. Yearly monitoring schedule for spring revisits at MOJN parks.

Park	Spring	Sampling Year						
		2019	2020	2021	2022	2023	2024	2025
LAKE	Blue Point	x	–		–	x	–	–
	Rodgers	x	–		–	x	–	–
	Grapevine	x	–		–	x	–	–
	Horsethief	x	–		–	x	–	–
MOJA	MC	deferred			–	x	–	–
	Piute Spring	deferred	–		–	x	–	–
	Cornfield	deferred	–		–	x	–	–
DEVA	Texas	–	deferred**	x	–	–	x	–
	Travertine	–	deferred**	x	–	–	x	–
	Nevares	–	deferred**	x	x	x	x	–
	Saratoga	–	deferred**	x	–	–	x	–
	Mound	–	deferred**	x	–	–	x	–
JOTR	Fortynine Palms	–	–		x	–	–	x
	Smith Water	–	–		x	–	–	x
	Cottonwood	–	–		x	–	–	x
PARA	Pakoon*	–	–		x	x	x	x
	Tassi	–	–		x	–	–	x
	Chill Heal	–	–		x	–	–	x

x = scheduled sampling year, dashes = not sampled

Deferred year at MOJA in 2019 to allow first year of sampling more time to plan and conduct field work.

* Pakoon Springs and Nevares Spring are examples of springs that are currently undergoing management; they are included in the schedule here to demonstrate how the calendar might look. MOJN has the capacity to conduct yearly monitoring at up to four springs that have active management. These springs are subject to change over time due to park management needs.

**DEVA was deferred in 2020 due to the pandemic

Monitoring at Actively Managed Springs

In addition to the 3-year revisit cycle, springs that are undergoing current on-the-ground park management efforts, such as invasive plant removal, can be monitored on a yearly basis. For example, Pakoon Springs in PARA underwent a major vegetation restoration effort in 2016 (J. Fox, pers. comm.), Nevares Spring in DEVA had non-native palms mechanically removed in 2015 (K. Lund pers. comm.), and MC Spring in MOJA had many plants mechanically removed in 2017 to maintain a specific level of exposed surface water for the endangered Mojave tui chub (D. Hughson, pers. comm.). These management efforts will create major disturbances at springs which should be monitored. Such springs will be monitored for a minimum of three years after the management effort and then return to regularly scheduled visits every three years. MOJN can invest one sampling week per year, potentially up to four springs each year, to monitor active management. MOJN will work

with park managers on a case-by-case basis to determine which springs warrant additional monitoring, since the location of springs and the logistics of monitoring them will determine the capacity to include additional springs. In terms of a field schedule for MOJN staff, this schedule results in sampling for 6 weeks/year, every year (Table 6).

Response Design

Sample Unit

To monitor species composition (monitoring objectives 1 and 2) and presence of disturbance (monitoring objective 4) within each selected spring, the sample unit is the transect line. The total number of sample units within a spring is a function of the total area of the spring (Tables 7 and 8). For species richness (monitoring objective 1) and overstory estimation (monitoring objective 3), the sample unit is a "belt transect." A belt transect is in the identical location as the Line Point Intercept (LPI) transect but are wider; belt transects extend 1.5 m on each side (3 m total width) of the permanent transect.

Table 7. For stream dominated springs, the total number of transects and the distance between those transects is a function of the length of the spring (as determined in the species accumulation curves below). Since the actual length of the riparian vegetation zone is dynamic, the spring lengths are placed in classes. Regardless of the number of transects and the distance between them, transects are always 15 m long.

Park	Spring	Length Class	Estimated Length	# Transects	Distance Between Transects
JOTR	Fortynine Palms	1	501 m-1000 m	8	30 m
	Smith Water	3	>1.5 km	12	40 m
	Cottonwood	3	>1.5 km	12	40 m
LAKE	Blue Point	2	1 km-1.5 km	10	30 m
	Rodgers	1	501 m-1000 m	8	30 m
	Grapevine	2	1 km-1.5 km	10	30 m
	Horsethief	2	1 km-1.5 km	10	30 m
DEVA	Texas	2	1 km-1.5 km	10	30 m
	Travertine	2	1 km-1.5 km	10	30 m
	Nevares	3	>1.5 km	12	40 m
	Mound				
PARA	Tassi	2	1 km-1.5 km	10	30 m
	Chill Heal	1	501 m-1000 m	8	30 m
MOJA	Piute Spring	3	>1.5 km	12	40 m
	Cornfield	2	1 km-1.5 km	10	30 m

Table 8. At pool dominated springs, the number of transects is based on the total area of the spring, since these springs are more round-shaped than linear. The estimated area of each spring was calculated using spatial imagery in Google Earth.

Park	Spring	Estimated Area (m2)	# of Transects
MOJA	MC	956	7
DEVA	Saratoga	75709	12
PARA	Pakoon	2045	8

Vegetation

This protocol collects four types of vegetation data: species composition, species richness, overstory composition, and presence of invasive plant species. All four of these data are collected along permanent transects at each spring (Figures 26 and 27). The number of transects at each spring is a function of the springs length or area, and therefore varies at each spring (Tables 7 and 8). However, all transects at all springs, regardless of the number of transects are the same length, 15 m. The relationships between the data collected and the monitoring objectives are outlined in Table 9.

Table 9. Relationship among measured variables, data, and objectives for long-term monitoring of spring vegetation communities in MOJN. Refer to Monitoring Objectives for a full description of each of the objectives.

Variable	Collection Method	Raw Data	Data Summaries	Monitoring Objectives
Species (plants and trees)	Line Point Intercept (pin drop for understory, moosehorn for overstory)	Nominal and % cover	% cover of each species, total % veg cover, % soil cover, proportion live/dead, presence and abundance of invaders	1. Status and trends of community 2. Status and trends of invaders 3. Status and trends of overstory species
Disturbance class	Line Point Intercept	Disturbance category	% cover of each disturbance class, total % cover of disturbance	4. Status and trends of disturbance
Species (all)	Belt transects (2m wide)	Nominal	Species richness (total # of species), Native species presence/absence, Community Diversity Index, targeted invasive species presence/absence	1. Status and trends of community 2. Status and trends of invaders

Table 9 (continued). Relationship among measured variables, data, and objectives for long-term monitoring of spring vegetation communities in MOJN. Refer to Monitoring Objectives for a full description of each of the objectives.

Variable	Collection Method	Raw Data	Data Summaries	Monitoring Objectives
Species (tree)	Belt transects (2m wide)	Nominal and % cover	Total tree species richness; total tree species diversity; abundance of each tree species, abundance of tree age classes; proportion live and dead; summarize for all species, and each species	3. Status and trends of overstory species
Species (invasive)	Opportunistic throughout spring (following IPSED methods)	Nominal and total % cover of spring	Presence/absence and abundance of invasive species	2. Status and trends of invaders

Species composition data will be collected using the LPI method along transects (see Figure 26; SOP 5). These data will be recorded in three vegetation layers: Stratum 1 (from 0-1 m above ground), Stratum 2 (1 m to 1.5 m above ground), and Stratum 3 (1.5 m and higher). We consider Stratum 1 and Stratum 2 to be the "understory," or plants that are closest to the ground. These plants are easiest measured looking directly down on the plants and dropping a pin-flag along the transect line. All species that touch the pin-flag are recorded. These plants are woody (such as shrubs or samplings) or herbaceous; if taller than 1 m and present below 1 m, individuals can be counted both in Stratum 1 and Stratum 2. Vegetation in Stratum 3 are "overstory" plants, or comprise the highest canopy of the riparian area. We consider vegetation that is woody and perennial to be the overstory. For example, *Typha domingensis* would not count as an overstory species, even if it is taller than 1.5 m, because it is entirely herbaceous. This stratum is measured by using a GRS Moosehorn Densitometer held at 1.5 m. We selected this method because it is more accurate to estimate with confined overhead space instead of projecting a pin-flag up and guessing what it might touch above 1.5 m.

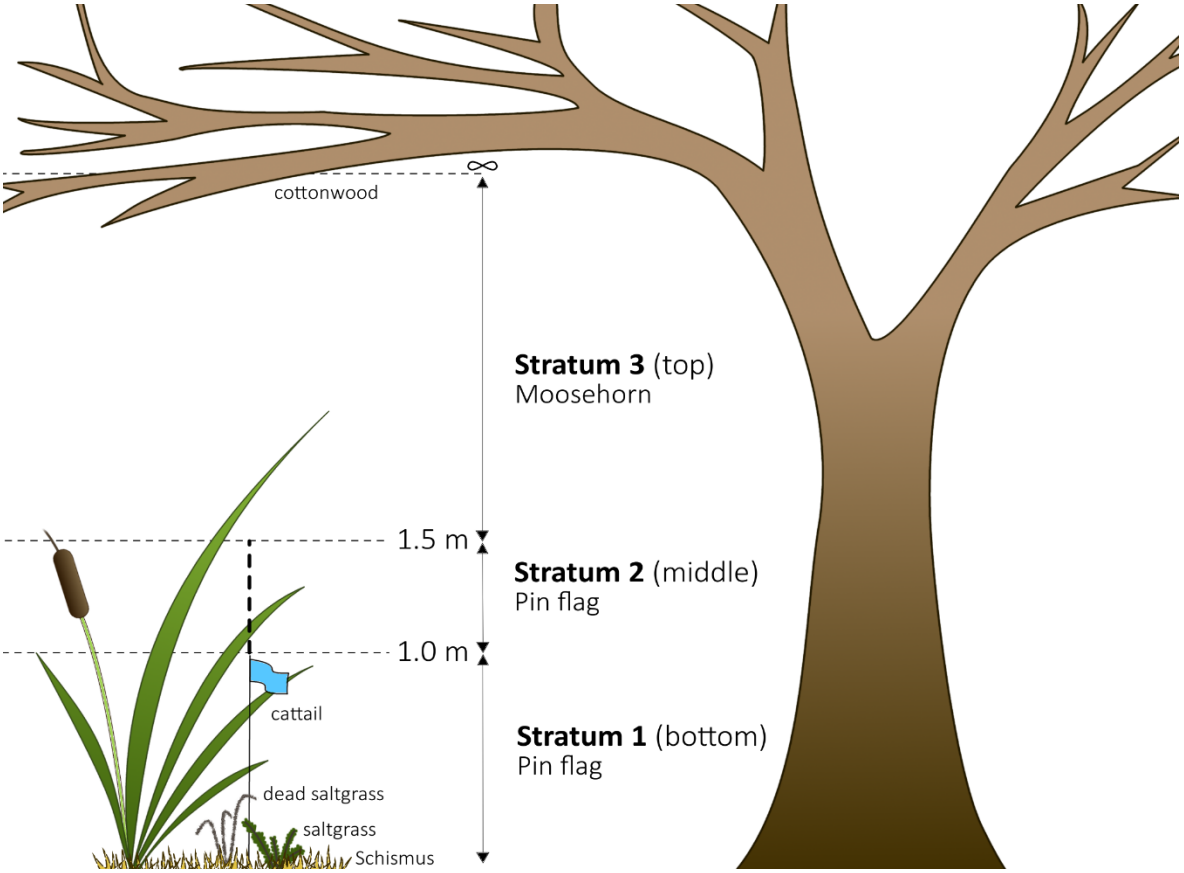


Figure 28. For species composition (understory and overstory) and disturbance, data will be collected using the Line Point Intercept method (LPI) along permanent transects. The three vegetation strata are measured using pin flags and the GRS Moosehorn Densitometer.

Overstory Composition is measured in two ways. Species richness is captured in LPI as Stratum 3 (Figure 26; SOP 5), and overstory cover is measured in belt transects that center on the permanent transect line and extend 1.5 m on either side (SOP 7). Belt transects are 3 m wide by 15 m long. All tree species of interest will be counted in the belt transect in categories: adults, juveniles (defined here as the early life phases of trees including both seedlings and saplings), and live and dead of both. The species monitored in belt transects are those which are of particular interest to the park or are especially charismatic to the spring (such as palm species and cottonwoods).

Species Inventory is also conducted in belt transects that center on the permanent transect line and extend 1.5 m on either side (SOP 6). Along these transects, observers record all species present. This systematic approach increases the probability of detecting rare or unique species at desert springs and will provide a more complete estimate of the number of species present at a spring. However, since this measurement will be time consuming, it will only be conducted every third visit to a spring (every 9 years) and will enlist the help of park managers when possible. This species inventory will likely require more time in the first sampling year than subsequent years; after the initial sampling year, observers will have a list of species for each spring which will ease some of the plant identification burden. MOJN staff will work closely with park managers, including them in the initial

species inventory if possible, to conduct this inventory. If species cannot be identified in the field, they will be carefully collected and identified in the office.

Disturbance at each spring is also measured along the transect using the LPI method (a full explanation of the disturbance classes is in Table 5.5 of SOP 5). When the pin-flag touches the ground, the observer records any disturbance (by class) at that point.

Invasive Plant Species are recorded along the transect using the LPI method, in the species inventory, and as an overall estimate. All observers in each crew will record any invasive plant species found at the spring even if it is not detected in one of the sample designs above. Any target invasive species will be searched for while the rest of the data are collected. Crews will use the invasive plant species list created in the IPSED plan (see Hupp et al. 2017 for full details), which includes park specific invasive plant lists, since the species of highest concern may vary across parks.

Photo-points will be established at every spring in at least one location as an overview. These photos will be taken from the same location at each revisit.

Sample Size Determinations

We determined the approximate number of transects needed at each spring to adequately sample the plant community using species accumulation curves which display pilot data collected in MOJA in 2017 and LAKE in 2016 (Figures 29, 30 and 31). In these curves, the cumulative number of species is displayed as a function of sampling effort. As classically described by Heck et al. (1975), species accumulation curves are useful to determine the sample size required for surveying species known to occur in a particular area. In these figures, as the amount of sampling effort increases, species richness also increases, but asymptotically. The point at which the curve asymptotes (i.e. the amount of species richness plateaus, or the curve "saturates") is the point at which an increase in sampling effort does not correspond to an increase species richness. In other words, when the curve levels off, collecting additional data does not result in detecting many new species because most of the species have already been detected (Gotelli and Colwell 2001). Sample sizes should be reconsidered using power analyses at each spring after the establishment year.

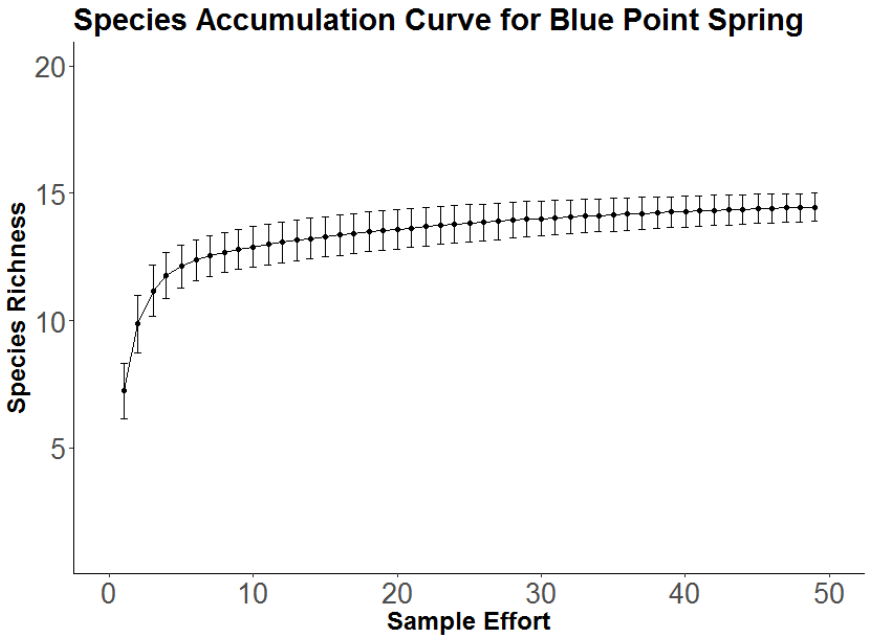


Figure 29. Species accumulation curve of pilot data collected at Blue Point Spring (a medium length spring; in length class 2) in November of 2016. Sample effort in this case (x axis) refers to number of transects sampled and the y axis is the number of species.

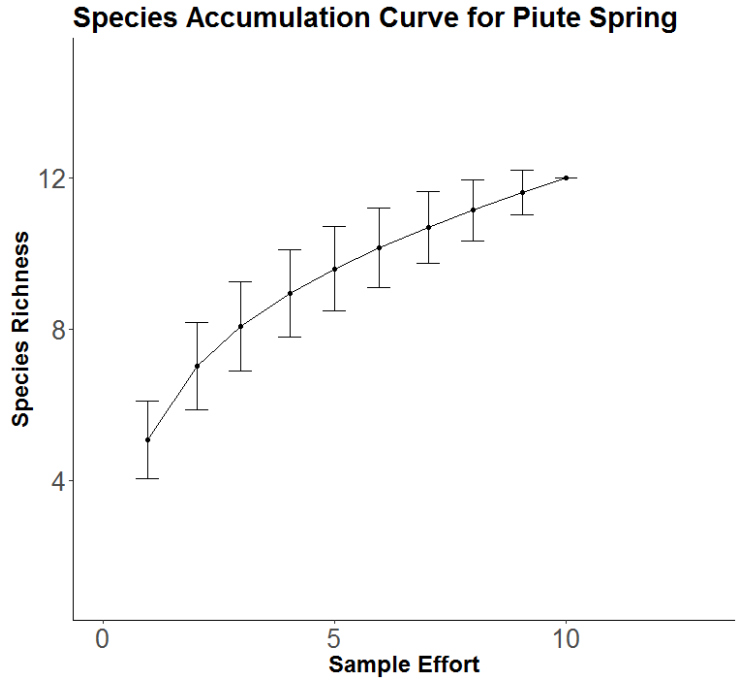


Figure 30. Species accumulation curve of pilot data collected at Piute Spring (a long spring; in length class 3) in November of 2017.

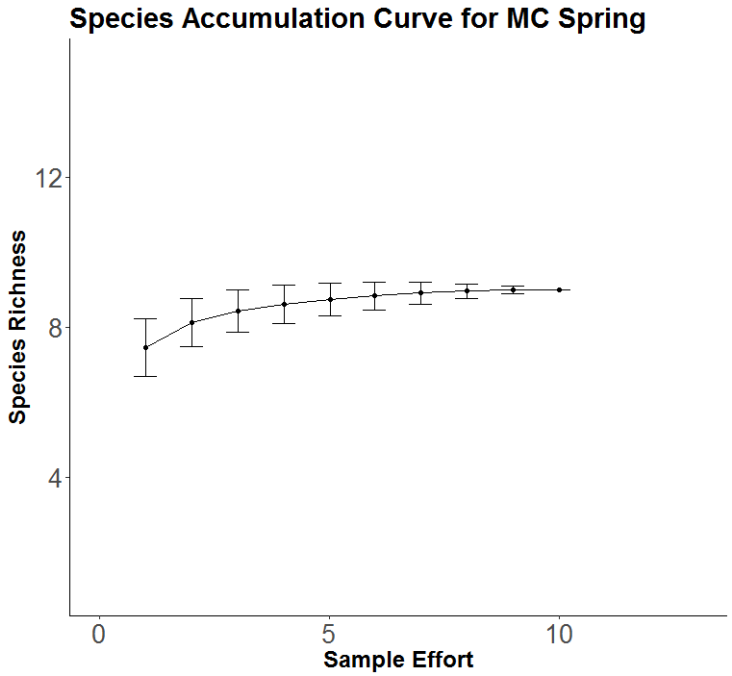


Figure 31. Species accumulation curve of pilot data collected at MC Spring (a short spring in length class 1) in November of 2017.

At Blue Point Spring in LAKE, pilot data were collected in 2016. This spring belongs in length class 2 ("1 km - 1.5 km." Tables 7 and 8). At this spring, it is clear that the inflection point of the curve is around seven samples, and it begins to level at 10 species. However, the pilot data were collected in winter when species diversity was likely lower than in spring. Therefore, a minimum of 12 transects will be established in the first sample year. This number should be revisited after the initial establishment year to confirm our estimate.

Piute Spring is also in length class 3 (">1.5 km"). This spring has higher species richness than Blue Point, and in the pilot data collection year, not enough data were collected to fully saturate the curve, though it does begin to taper at 10 transects. Again, 12 transects will be installed here, though this number should be revisited after the establishment year.

In Figure 29, the species accumulation curve for data collected at MC Spring appears to asymptote at nearly five samples. Again, since these pilot data were collected in the winter when species richness might be at its lowest, seven transects will be established at this spring in the first sample year.

Field Methods

The Standard Operating Procedures (SOP) associated with this protocol (Springs in the Mojave Desert Network— Vegetation Monitoring at Selected Large Springs: Standard Operating Procedures Version 0.1 [Hupp et al. 2018]) provide step-by-step field sampling methods, logistics, data collection and entry methods, data management, and data analysis and reporting procedures (Table 10). SOPs are organized by field sampling procedure and activities. Personnel that are involved in this protocol are required to have read and be familiar with the SOPs in addition to any Network-wide SOPs that are mentioned in this protocol document or associated SOPs document (Hupp et al. 2018). Note that MOJN has a specific safety protocol that is not included in the SOP document listed above: since safety is a major component of all MOJN projects, the Network has a stand-alone document that is updated more frequently than most SOPs (Mojave Desert Network Inventory & Monitoring Field Safety Plan [Tallent et al. 2017]).

Table 10. MOJN Desert Spring Vegetation Monitoring SOPs.

SOP	Description
1	Preparation for the Field Season
2	Training Observers and Plant Identification
3	Locating Springs
4	Site Establishment
5	Measuring Vegetation Using the Line Point Intercept Method
6	Species Inventory
7	Overstory Composition
8	Invasive Plant Assessment
9	Crust Friendly Procedures
10	Disinfecting Gear
11	Unknown Plant Species
12	Data Management
13	Data Analysis and Reporting

Field Season Preparations

The protocol and all SOPs are reviewed by the Project Lead to ensure that any changes to sampling procedures have been updated prior to the beginning of every upcoming field season. Specific park applications for research permits are available at the Research Permit and Reporting website (https://science.nature.nps.gov/research/ac/ResearchIndex). Wilderness compliance, minimum tool analyses, and park housing, camping requests, or access key requests are completed and submitted to the proper divisions well in advance of the field season. Global Positioning System (GPS) devices are loaded with locations of all plots to be visited in the coming field season. Electronic field data collection devices (usually tablets), if available, will be loaded with a portable version of the database. Hardcopy paper field data sheets will be printed on regular paper and on *Rite in the Rain* waterproof paper and used either as a backup in the event of tablet failure or as the primary data

collection method if tablets are not available. Equipment is checked against the equipment list (SOP 1), and repairs or purchases are made as needed to complete the list. Biological technicians are hired either as park service employees or through cooperating organizations. In either case, the hiring process is initiated well in advance of the field season.

Training, Calibration, and Consistency

Proper training is paramount to the success of this project; Field Crews receive thorough training each year with a combination of indoor and outdoor instruction. Training will be conducted by the Project Lead and the MOJN Data Management Team, or other appropriate staff members. All crew members will review the protocol narrative and SOPs independently, then the training staff will give detailed instruction on how to use sampling and navigation equipment, methodologies for data collection, species identification, and how to effectively work in desert springs with minimal ecological impact. An assessment of crew competencies should be made toward the end of training to identify and correct errors in technique, approach, or understanding. The assessment tests both understanding of material and field methodology. Values for variables that are estimated rather than directly measured are compared among crew members and any broad deviations discussed and corrected. Training will be completed within one week (five days) at the start of each season and as described in the SOPs.

Locating and Establishing Plots

Driving directions to park study areas are discussed in SOP 3. Once on site, access to sampling areas will require hiking across rugged terrain, backcountry camping, and field teams must be prepared for challenging weather conditions, including extreme heat, cold, rain, and snow. Safety procedures should be adhered to, including maintaining close communication with office-based park points-of-contact, such as park resource managers, regarding field schedules and check-in/check-out times. Park hazards, including emerging threats such as extreme weather or fire hazards, should be discussed with park staff during a kick-off meeting prior to initiation of field work and throughout the duration of sampling, as necessary. First aid and other safety equipment must be kept in project vehicles and easily available at all times.

Transects at each spring will be re-located using GPS following procedures outlined in MOJN general SOP *Using Garmin 76CSx GPS Devices* (Lehman 2017) and finding monuments. Plot locations and trip routes are displayed on hard copy maps and entered into GPS units. The crew and the appropriate staff members review trip routes and discuss potential dangers (e.g., river crossings), contingency plans, and notes and experiences from previous trips for plot revisits. Travel routes will be illustrated on hard copy maps and annotated during close-out of the previous season, drawing on accumulated field experience. This is a good time to check that each crew member's compass is adjusted to the correct declination.

Crew members navigate to transect locations using map, compass, and GPS. At the first visit, crews follow the site establishment procedures (SOP 4). If this is a revisit to a location where permanent markers are allowed (e.g., the site is not in a Wilderness area), the plot monument marker (e.g., metal rebar) is found using observations, a GPS unit, a metal detector, and notes from previous visits and plot photographs.

Measuring Response Variables

A digital photograph is re-matched at the beginning of each plot visit. Springs are then sampled by locating markers for the first transect and using a taut meter tape on the transect line (SOPs 5, 6, and 7). After that, transects are sampled in order from the top or highest point of the spring to the bottom, or lowest point. The bearing of the transect direction is dependent on the spring and must be confirmed with the database before entering the field. Vegetation data at the springs will be collected in order at each transect: species inventory (if it is the appropriate sample year to collect these data), LPI, and tree belt transect. To reduce trampling, all transect related procedures should be implemented sequentially on each transect, rather than completing one SOP at a time across the spring (i.e., completing LPI on all transects and then completing species inventory on all transects).

After the Field Season

Equipment is compared against the equipment checklist to make sure it is all accounted for. Equipment is inspected for damage and replaced if needed. Batteries are taken out of all electronic devices prior to storage. All gear should be decontaminated, cleaned with rubbing alcohol or another solvent, and any missing flagging from gear should be replaced. All sampling gear is stored in the MOJN Ready-Room or "conex" storage container in Boulder City, Nevada.

All unknown plant species will be identified to the lowest taxonomic level possible by MOJN staff using all relevant plant keys and park herbaria. If species cannot be determined, MOJN will work with the vegetation staff at each MOJN park to identify species. Park staff may also share contact information with other local experts to assist in identification, which varies across parks. Identified unknown species will be updated in the Desert Spring Vegetation database, and a description of the species will be generated for the next Field Crew.

Field Crews will be debriefed by MOJN staff, Protocol Lead, and the Field Lead. Crews will be asked for suggestions on logistics, training, field methods improvement, equipment needs, etc. Adopted suggestions will be incorporated into the relevant SOPs before the next field season.

Data entry on incidental observations of invasive species will be completed within two months following MOJN IPSED procedures so that locations of targeted invasive species can be provided to park staff and the EPMT for removal.

Data Management

Effective data management is critical to ensuring the quality, interpretability, security, longevity, and discoverability of the data produced by our monitoring efforts. The principles of sound data management as they apply to I&M networks are defined in the national data management plan (NPS 2008a). This narrative will describe in general terms how these principles will be applied to the spring vegetation monitoring effort at MOJN. A detailed set of procedures for all data management tasks can be found in SOP 12.

Data collection and database design

Data collected in the field will be recorded on paper datasheets until an electronic data collecting system is deemed practical. Before leaving a spring, the crew leader is responsible for ensuring that all forms have been filled out completely and that the information on each form is logical and legible. Upon returning from each field trip, datasheets will be stored in the MOJN incoming data sheet cabinet and will move through a series of color coded folders as the data entry, review, and scanning to PDF steps are completed. The Protocol Lead is responsible for safekeeping and organization of the datasheets until data entry and verification procedures have been completed. At this point, the Data Manager is responsible for datasheet storage and archiving. The scanned versions of the field data sheets will be organized on the MOJN shared drive.

Data will be stored in a SQL Server relational database with a Microsoft Access front-end for data entry and quality control and quality assurance (QA/QC) processes. The database design is inspired by the Inventory and Monitoring (I&M) program's Natural Resources Database Template (NRDT) but with modifications which bring it in line with the 2015 Inventory and Monitoring Division database standards (Frakes et al. 2015), and the 2017 Inventory and Monitoring Division's (IMD) Minimum Implementation Standards (Frakes 2017). The database will track the QA/QC processes (data processing level) that have been applied to each site visit activity and will store a "line of sight" to the full package of protocol materials that were in place at the time that the data were collected. The database will store metadata for photographs taken as part of each site visit. The photograph files will be renamed and stored as described in SOP 12.

Any time a revision of the protocol requires a revision to the database, a complete copy of the database will be made and stored in a read-only archive directory.

Data entry, verification, and validation

Data entry

The primary goal of data entry is to transfer the data from paper into the database with 100% accuracy. Ideally, this should be undertaken during the field season in order to provide the best opportunity to correct data omissions or ambiguities. When this is not practical, it should occur as soon after the field season as possible (ideally by those who collected the data). Data entry should be completed by someone who participated in data collection or is familiar with the project and data. Database backups will occur regularly to maximize the ability to recover from any irreversible errors or problems that occur during the data entry session.

Data verification

The spring vegetation database application will incorporate QA/QC strategies to ensure data quality. The database design and the allowable value ranges assigned to individual fields within the data tables help to minimize the potential for data entry errors and/or the transcription of erroneously recorded data.

SOP 12 describes the steps that the Protocol Lead and data management staff will take to ensure that the data records within a given season's dataset are verified (i.e., database values are compared against hard-copy datasheets). The goal is to check 100% of records and to correct and track any errors discovered. Errors and inconsistencies that cannot be corrected will be documented and included in the metadata and certification report. The completion of data entry and data verification will be tracked in the database.

The Protocol Lead or Data Manager will verify the geospatial component of the spring vegetation database each field season.

When data verification is complete, the dataset is considered to have reached the "provisional" data processing level. The data processing levels referred to in this document are more fully described in "Certification Guidelines for Inventory and Monitoring Data Products" (NPS 2016).

Data validation

The Protocol Lead and data management staff collaboratively validate a given season's dataset (i.e., ensure that the data make sense). Some validation methods that check for outliers, missing values, and illogical values have been incorporated into the database. Other, more specific, validation routines are developed in collaboration with the Protocol Lead and will be incorporated into the database as appropriate. Data management staff will work closely with the Protocol Lead to provide any needed database queries, reports, graphs, or export file formats to assist with the overall validation.

Data certification and documentation

Once the data are validated, the Data Manager and Protocol Lead will complete the necessary accompanying metadata. Metadata are defined as structured information about the content, quality, condition, and other characteristics of a given dataset. Additionally, metadata provide the means to catalog and search among datasets, thus making them available to a broad range of potential data users. Any records that did not meet the documented quality standards in the validation process must be clearly identified in the metadata.

When this process is complete, the dataset is considered to have reached the "accepted" data processing level and is suitable for reporting and distribution. Until a full Quality Assurance Plan is implemented for this protocol, "accepted," rather than "certified," is the highest data processing level that may be achieved.

Data distribution

Prior to publication of any reports or data, MOJN staff will work with staff from each park represented in the dataset to assess the sensitivity of the dataset. The results of this assessment will

dictate the appropriate audience for the data: Park only, NPS only, or public. Redacted datasets and reports may be created when it is deemed that sensitive information should be obscured for one or more of these audiences. The sensitivity or "protected status" of species and location data will be tracked in the database following the guidance in the IMD document Minimum Standards for Network Projects (Frakes 2017).

As part of the reporting cycle, summary reports and derived data products will be made available on the IRMA Data Store (https://irma.nps.gov/DataStore/).

Data maintenance and archiving

Secure data archiving is essential for protecting data files from loss or corruption. Once the master project dataset and metadata are considered final for a field season, the Data Manager will place a copy of the dataset and the metadata record into the appropriate folder within the archive directory on the MOJN shared drive, which is backed up to a remote location. These archived files will be stored in read-only format. Any subsequent changes made to this database must be documented in an edit log and in the metadata. In addition to the database copy in its native format, all tables will be archived in a comma-delimited ASCII format that is platform-independent. A full copy of the project master dataset will be uploaded to the IRMA Data Store on an annual basis.

Additional digital files to be archived include all digital photos associated with that field season and any digital files associated with data analysis products and project reporting.

Hard-copy materials (e.g., datasheets, field notebooks) will be stored in the network office for at least four years, and will eventually be moved to an NPS-approved repository for permanent storage.

Any editing of archived data must be documented in an edit log and accompanied by an explanation that includes pre-and post-edit data descriptions. This ensures that there are no unexplained discrepancies between the original datasheets and the archived data, or between different versions of archived datasets.

Data Analysis and Reporting

Three types of reporting are associated with the MOJN Spring Vegetation protocol: annual data, trends reports, and resource briefs. All analysis and reporting of this protocol is directly linked to monitoring questions and the four long-term monitoring objectives of this protocol (the abbreviated objectives are monitor: status and trends of vegetation community, status and trends of invasive plants, status and trends of overstory, and status and trends of disturbance). While incorporating supplementary analysis that has ecological relevance is encouraged, the protocol objectives must be adequately addressed. Data included in the reports will consist of status analyses and trends analyses, which are described in detail below.

Status Analysis

Status analysis is used to describe the current state of the spring vegetation and may be obtained for all parameters of ınterest in this protocol. Status analysis will be the primary content in the Annual Status Reports and will be included in Resource Briefs when appropriate (suggested methods are described in SOP 13). Status analyses include basic summary statistics such as the calculation of the mean, median, variance, minimum, maximum, sample size, and range, as well as appropriate exploratory analysis. Standard summary statistics and exploratory analysis should be presented in figures and tables and should include measures of central tendency and spread.

Annually, the Protocol Lead should conduct exploratory analyses to share relevant findings with the parks and to conduct a basic check-in with the protocol. These procedures are important to ensure our data meet the underlying assumptions of statistical techniques (e.g., assumption of normality), help reduce type I and II errors, and thus minimize the risk of formulating incorrect ecological conclusions. Exploratory data analyses should be used to refine existing hypotheses, and they can help generate new hypotheses about patterns and processes. Some examples of parameters that should be investigated in status analysis and exploratory analysis include:

- Mean % cover across transects of each species grouped by stratum (bottom, middle, top) and live/dead status.
- % cover of any species of interest, total % veg cover, % soil cover
- % cover of each disturbance class, total % cover of disturbance
- Species richness (total # of species), native species presence/absence, a community diversity index (such as Shannon Diversity Index)
- Total tree species richness; total tree species diversity; abundance of a particular tree species; abundance of tree age classes; proportion live and dead, summarized for all species, and each species
- Presence/absence and abundance of invasive species

Trend Analysis

Trend analyses show how vegetation at springs are changing through time. These analyses are in-depth and will be conducted once sufficient data have accumulated to estimate trends (suggested analyses are conducted with R code and described in SOP 13). Trends results are summarized in Trends Reports after 3 or more years of data collection (9 calendar years). Trend analyses will be presented in figures and modeling output; raw data are available for park managers to view. Data are analyzed by species and spring. Trend analyses will be included in the Resource Briefs when appropriate.

If disturbance events occurred at springs, data will be modeled before and after the disturbance using repeated measures ANOVA to understand how the plant community has changed over time. This method is useful for sites that are permanent where measures are taken at the sample place using the same methods over time. Using repeated measures ANOVA, the Project Lead can use relevant temperature, precipitation, and other climatic variables, as well as data collected in SLS protocol. The usefulness of these variables should be determined using backwards elimination, and only relevant predictors should be included.

Trend analysis will directly address the four measurable objectives: trends of the vegetation community, trends of invasive plants, trends of overstory, and trends of disturbance (see Background section for expanded definitions). We suggest using mixed effects models to address the measurable objectives. Mixed effects models are useful to determine if, and to what extent, they are changing over time. These models are necessary because they allow both fixed effects (things that affect all samples consistently) and random effects (factors that vary from sample to sample). Using a mixed effects model, the Project Lead can use relevant temperature, precipitation, and other climatic variables, as well as data collected in SLS protocol. The usefulness of these variables should be determined using backwards elimination, and only relevant predictors (and with the appropriate transformations) should be included in the model.

For each vegetation variable of interest, the null hypothesis is the same. The null hypothesis (H_0) that there is no difference in [the vegetation variable of interest] within individual springs will be tested with a repeated measures nested analysis of variance (ANOVA). Initially, the trend analyses will be performed on data from only two points in time, however as more data becomes available (i.e. after three sampling periods), the trend analyses will be conducted using a mixed effects model designed to evaluate trajectories. All analyses will be performed using the statistical analysis software R. See the model equation and full trend analysis details in SOP 13.

Reporting

Annual Status Reports

Since field data collection occurs every year, we anticipate that MOJN will produce at least one Annual Status Report for this protocol each year. This means each park will receive a park-specific Annual Status Report for each year that monitoring occurs in the park. This will typically be at the 3 year interval for each park as described in the monitoring calendar (Table 6), but may be more frequent if supplemental monitoring has occurred. The Annual Status Reports will be provided

directly to park managers and will be in the form of a reproducible report and include additional documents if needed. The content and layout of reproducible reports are based on currently available technology, such as RMarkdown, a type of script created in the statistical program R which creates interactive figures. Reproducible reports are a useful format for Annual Status Reports because they can be quickly created and shared, which reduces the amount of time park staff must wait to receive monitoring information.

The Annual Status Report will include the following:

- A description of the field work, including documentation of any deviations from the protocol, such as missed sites or measurements.
- General summary statistics and graphs for the core components of the protocol
- Quality assurance and quality control analyses

Additional detail about the contents of these reports can found in SOP 13.

Trends Reports

Once all springs in a park have been sampled three times (9 years as scheduled), MOJN will prepare a Trends Report for that park (SOP 13). These reports will synthesize the information presented in the Annual Status Reports and provide statistically rigorous assessments of trends in the data within springs. After the first report, they will be prepared every 9 years. In other words, since the monitoring schedule specifies that all springs will be visited every 3 years, and those undergoing monitoring will be monitored every year, we will have at least 3 years of new monitoring data to create a long-term trend report. The Trends Reports will be published in the peer-reviewed NPS Natural Resource Report (NRR) series.

In addition to summarizing the collected data, the Trends Reports will include the following information:

- An overview of the protocol status and major accomplishments
- The status and trend analysis results
- A summary of relevant MOJN data from related protocols such as SLS
- A discussion of results, including management implications
- An in depth discussion and analysis of quality assurance and quality control
- Recommendations for future improvements to the protocol or data management strategies if needed (e.g., update sampling schedule based on actual trends, add GIS tools that were not developed at time of protocol development, and new analytical procedures that we deem relevant after initial trends are detected).

Resource Briefs

Along with Annual Status Reports, MOJN will prepare a 1-2 page Resource Brief that will provide a concise summary of the status of the protocol for years that have particularly interesting findings. These Resource Briefs will be provided to parks and written in a style that will allow interpretative staff to directly use relevant sections to tell accurate, science-based stories about the parks. Associated electronic materials, such as figures, can also be made available to parks, if needed.

Resource Briefs may also be created to accompany Annual Status Reports when there is a story that merits quicker and broader distribution than it would otherwise receive.

Personnel Requirements and Training

Personnel Requirements

This protocol requires close collaboration between MOJN staff and the staff of the network parks. Key MOJN staff members include: Ecologist (Protocol Lead), Program Manager, Data Manager, Assistant Data Manager, Field Lead, and Field Crew (the roles and responsibilities of all personnel are further described in SOP 6).

Roles and Responsibilities

The Protocol Lead will perform data analyses and reporting and will coordinate with the appropriate staff to oversee field implementation, data collection, and archiving of data. The Protocol Lead will help organize field logistics and obtain park research permits. The Protocol Lead will work with the Program Manger to hire seasonal technicians. The Protocol Lead will be supervised by the MOJN Program Manager and will frequently interact with the MOJN Data Manager to coordinate database development and data archiving.

The Program Manager will supervise the Protocol Lead and provide overall administrative and scientific leadership for all monitoring activities.

The Data Manager will develop and maintain databases for data generated by this protocol, maintain data management SOPs and all data for the protocol, and upload data to national databases.

The Field Lead will oversee the Field Crew both in the field and in the office. The Field Lead will organize all field logistics, organize field schedules, organize necessary field equipment, and contact appropriate park personnel. He/she will also provide QA/QC of field data, including conducting Field Crew checks to minimize observer bias, schedule Field Crew time for data entry, help the Protocol Lead and Data Manager with data management, and provide the initial data quality check against the field data sheets. The Field Lead is a critical link between the Field Crew and MOJN office and will be the first to hear about any protocol implementation issues. The Field Lead will work with the Protocol Lead to implement field work and schedule Field Crew time. The Field Lead will also work with the Data Management Team to ensure that all data management procedures are followed.

The Assistant Data Manager assists with data entry, QA/QC of data, and managing the protocol data.

The Field Crew implements the field procedures at each park and collects the field data.

The park Resource Managers consult on all aspects of the protocol, from protocol review to implementation, and will generally serve as the point of contact to MOJN during field implementation at their respective parks.

Qualifications, Training, and Calibration

We expect the Field Lead and Field Crew to have strong botanical skills, great attention to detail, and backcountry travel and camping skills. Ideally, they will be familiar with the plants of the Mojave Desert and nearby regions and have the ability to identify any unknown shrub species that they come across. Additional qualifications are knowledge of basic soil science, experience taking vegetation

monitoring measurements, familiarity with local environmental conditions and hazards (travel in remote backcountry, rough terrain, and extreme heat), good physical fitness, familiarity with GPS units, basic orienteering skills, and basic computer data entry. The Field Lead should also have field logistics experience and good organizational skills. Crew members should also have good organizational skills, memory retention, and the ability to work methodically and consistently under difficult conditions.

All crew members will train together. At the start of each field season and before starting at each park, the Field Lead will calibrate procedures across the crews in the field. At the beginning of the field season and under the guidance of the Field Lead, each crew will practice locating transects and taking vegetation, disturbance, and invasive species status and trends measurements. Crew members will reciprocally measure the test transect to make sure that crew members' measurements are consistent with each other. Calibration will continue until each crew member is consistently counting within 5% of the "true value," as established by precision within successive counts, or, if necessary, as established by the Field Lead. Precision and reproducibility measuring exercises undertaken throughout the field effort will provide additional opportunity for refinement and calibration of field techniques. Spring vegetation, disturbance, and invasive species training should be accomplished in two to three days, with the caveat being that additional days will be needed to expose crews to the project overview, GPS, data management, safety, and other training as needed.

Before entering the field, Field Crew members will undergo basic backcountry and safety training (e.g., NPS Operational Leadership, CPR/first aid, and wilderness first aid), 4WD training, field methods training, and desert spring vegetation identification and invasive species training. Field Crews must be proficient in all aspects of the sampling procedures, adept at using a GPS and/or compass and map to navigate to field sites, and able to work independently and safely in the backcountry. Details on training for safety, the protocol methods, and park specific training requirements are outlined in SOP 2.

Operational Requirements

Annual Workload and Schedule

The annual workload of this monitoring protocol is outlined by the "Time Allotted" column below in Table 11. The annual implementation schedule (Table 6) should be cross referenced with the proposed sample design, as different parks will be sampled in different years and sampling periods. An evaluation of the protocol and any necessary changes must be made four months prior to each sampling period. Since the MOJN parks have different growing seasons, the exact timing of the implementation schedule will vary slightly from year to year and depend on individual parks and weather conditions.

Facilities and Equipment Needs

A list of necessary and recommended field sampling equipment is described in SOP 1. The Field Lead will ensure that all equipment is in good working order and that there is an adequate supply of any consumables.

Field Crews will use park housing when available, camp at designated campgrounds when working at field sites, or backcountry camp for remote sites. MOJN staff will work with park staff to arrange for housing and camping in advance of the field season.

A minimum of one dedicated 4WD vehicle will be required to support each field season for this protocol. Periodic access to at least another 4WD vehicle is necessary for MOJN staff to meet with crews and conduct field checks. Currently (2017), MOJN has three 4WD vehicles, enough to support this and other protocols. If additional vehicles are needed, MOJN has been able to periodically borrow 4WD vehicles from LAKE when they are not in use. Backcountry safety procedures require that all 4WD vehicles be equipped with at least two spare tires when traveling to PARA.

Budget

The estimated annual operating budget for the Spring Vegetation protocol is outlined in Table 11.

Table 11. The approximate annual budget for spring vegetation monitoring in the MOJN. This budget does not include equipment costs because existing equipment will be used.

Personnel Type	Position	Time Allotted	Cost in Dollars
Permanent NPS Personnel	Network Program Manager (GS13)	1 week report review, hiring, and training	2,360
	Data Manager (GS11)	1 week database maintenance and preparing field data collection device; 1 week field season prep; 1 week QA/QC, data archiving and close-out	1,600 1,600 1,600
	Ecologist (GS11)	1 week hiring and training; 1 week sampling; 1 week analyzing data and report writing	1,600 1,600 1,600

Table 11 (continued). The approximate annual budget for spring vegetation monitoring in the MOJN. This budget does not include equipment costs because existing equipment will be used.

Personnel Type	Position	Time Allotted	Cost in Dollars
Permanent NPS Personnel (cont.)	Crew Lead and Logistics Coordinator (GS07)	1 week preparing and training; 3 weeks field work; 1 week season closure	1,120 3,360 1,120
Seasonal Personnel	Field Technician 1 (GS05)	3 week sampling; 1 week data input and QA/QC	2,400 800
	Field Technician 2 (GS05)	1 week preparing and training; 3 week sampling; 1 week data input and QA/QC	800 2,400 800
TOTAL	–	–	$4,760

Trend Reports will be produced approximately every nine years. The production of a Trend Report will primarily involve the Protocol Lead, a statistical consultant, and the Network Program Manager as peer review manager for the report. During the first year that Trends Reports will be produced, the Network Ecologist (who is the Protocol Lead) will spend approximately 0.25 time/year ($22,500) and the statistical consultant 40 hours ($4000). This time includes the production of an Annual Status Report and other products (e.g., figures) that will be directly available to the parks. Subsequent Trend Reports will likely require less time from the Network Ecologist, as a general report template will be established.

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NPS 963/148510, September 2018



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