2018 Springs Ecosystem Symposium

Training and Workshop

4-6 June, 2018

Museum of Northern Arizona

3101 N. Fort Valley Rd. Flagstaff, AZ, USA

Vaseys Paradise in Marble Canyon, Arizona. Photo by Abe Springer

This page left intentionally blank

Preliminary Program

2018 Springs Ecosystem Symposium

Training and Workshop

4-6 June

Museum of Northern Arizona

3101 N. Fort Valley Rd. Flagstaff, AZ, USA

Meeting Committee

Meeting Organizer	Larry Stevens
Technical Organizer	Edward Schenk
Sponsorship	John Spence
Program Manager	Jeri Ledbetter

Sponsors

Glen Canyon Natural Recreational Area

Glen Canyon Natural History Association

Museum of Northern Arizona

Springs Stewardship Institute

General Information

The meeting takes place in Flagstaff Arizona at the southern margin of the San Francisco volcanic field and the iconic Colorado Plateau. The city lies at 7000 feet (2100 m) within the largest contiguous Ponderosa pine (*Pinus ponderosa*) forest in the world. Flagstaff is known as the home for Northern Arizona University, one of the largest US Geological Survey campuses, the Powell Observatory (where Pluto was discovered in 1930), and the Museum of Northern Arizona. The meeting is in early June where the weather tends to be sunny, dry, with reasonable temperatures.

Be sure to check out Flagstaff's dynamic downtown during your visit. There are many outdoor opportunities in the area including the red rock canyons and trails of Sedona (45 minutes to the South), Walnut Canyon, Sunset Crater, and Wupatiki National Monuments on the east side of Flagstaff, and the Grand Canyon a 1.5 hour drive to the North. There are numerous websites and books that can provide you with ideas and information for your visit.

Presentations will take place over two days including keynote talks highlighting major themes in springs ecosystem science and a one hour moderated discussion on the current state of springs monitoring protocols and efforts and potential future directions that would be advantageous for springs stewardship and restoration. The entirety of the symposium will take place on the campus of the Museum of Northern Arizona.

Venue

The Museum of Northern Arizona is located approximately 3 miles North of Flagstaff's downtown on Highway 180. The majority of the meeting will take place in the Branigar-Chase Auditorium located near the highway facing entrance nearest the parking lot. The social mixer on the evening of June 4th will take place in the side courtyard of the Museum and can be accessed by the same doors. Ample free parking is available at the Museum or across the highway at the Easton Collection Center. See maps for more information.

Transportation

Flagstaff is accessible by air, Amtrak, and Interstates 40 and 17. The Flagstaff-Pulliam Airport (FLG) is served by American Airlines with limited service from Phoenix, Los Angeles, and Dallas. Flights into Phoenix can use the Arizona Shuttle Service, a 3 hour van shuttle ride to Flagstaff (www.arizonashuttle.com) or can access Flagstaff by rental car in 2 to 2.5 hours. The Museum is 3 miles from the Amtrak station, 4 miles from the Greyhound station, and approximately 5 miles from the airport. The city bus system provides bus service to the Museum using the #5 line (https://mountainline.az.gov/routes/route-5-orange/) and there is a bike lane from downtown that passes the Museum (https://www.flagstaff.az.gov/1521/Flagstaff-Urban-Trails-and-Bikeways-Map).

Information for Presenters

All presentations will be in the Branigar-Chase Auditorium. We strongly recommend that you arrive early to load your presentation onto the computer. The computer will be in the Auditorium and will be running Windows (Mac/Linux users please check your formatting to ensure that it works on a Windows version of Microsoft Office). Please label your Powerpoint with the primary presenter's last name and then the name of your talk. If possible upload your talk on the morning of June 5th between 8 and 9 am. Keynote speakers will have 30 minutes including questions, presenters will have 20 minutes including questions. There will be a one hour moderated discussion on the second day about the state of springs monitoring and what future tools and directions would be helpful for on-the-ground springs stewardship and restoration.

Food Options

Your registration fee pays for light food options during the social mixer on June 4th and for lunches on June 5th and 6th. A cash bar will be available between 5pm and 8pm on June 4th in the courtyard of the Museum of Northern Arizona. Catered options for both the mixer and the lunches include both vegetarian and omnivore plates. There are also numerous restaurants and fast food options in downtown Flagstaff (3 miles) as well as along the Highway 180 corridor. Water and coffee will be provided at the meeting, we highly recommend bringing your own water bottle(s) to reduce waste and keep the conference space clean.

Weather

Weather in early June in Flagstaff is sunny, cool to warm, and commonly windy. High are usually in the 60s and 70s (15-25 C) with cool to cold nights. We recommend wearing layers as the high altitude semi-arid environment can lead to a wide range of temperatures throughout the day.

Registration fees

There will be no onsite registrations, please register before the meeting using the website (http://springstewardshipinstitute.org/springsecoscience2018information/) or by calling the Springs Stewardship Institute at (928) 774-5211 x231. Cancellations are accepted with a $25 fee until May 15th, all cancellations after May 15th will not receive a refund.

Accommodations – Lodging and Camping Options

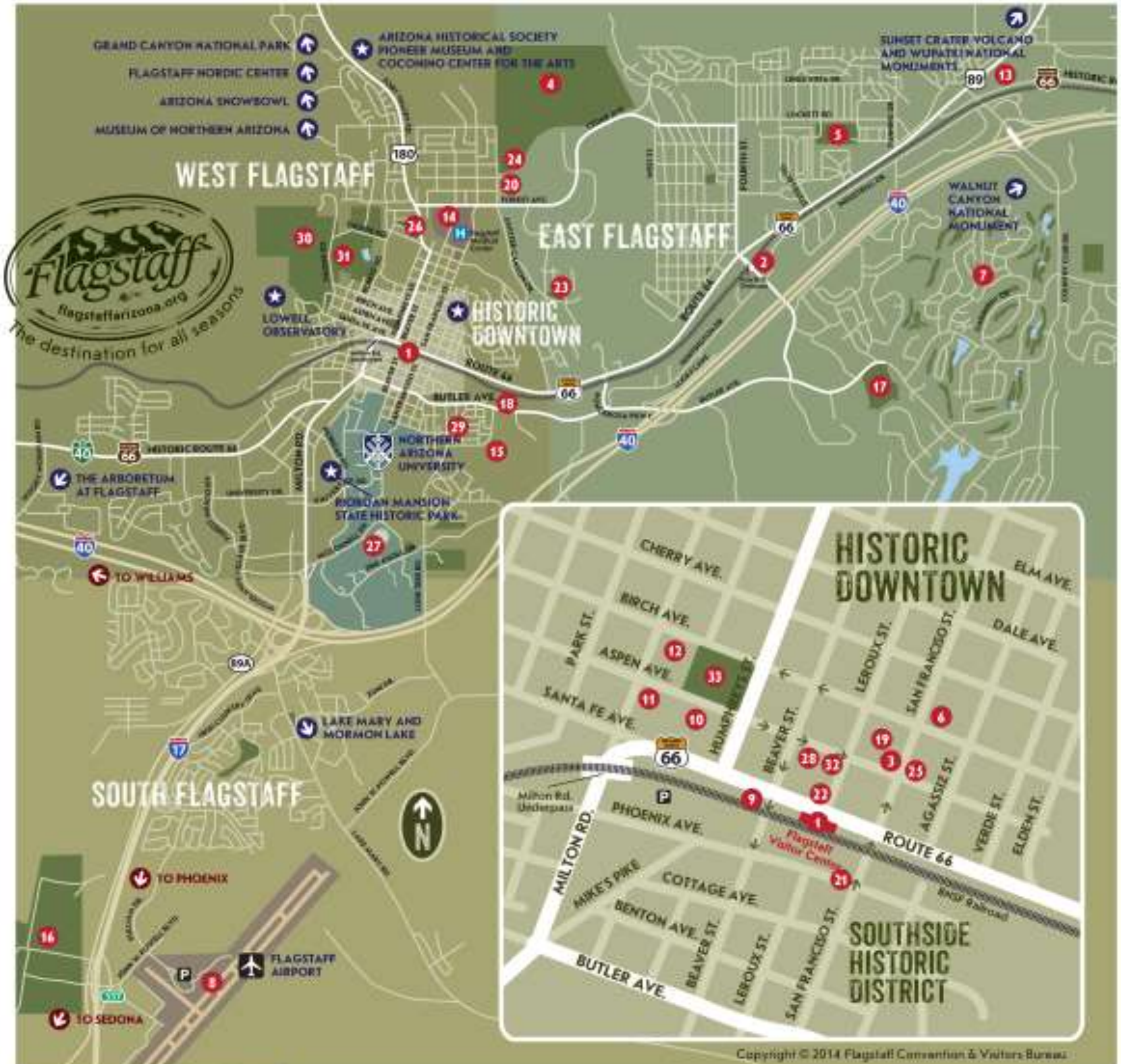
There are numerous hotels and motels in Flagstaff with prices ranging between $60 to $200 night depending on quality. There are also hostels, AirBnB, and VRBO options. Free dispersed camping is available in the nearby Coconino National Forest. Be sure to check with forest to determine if there are any closures, wildfires, or other events that my impact your stay (https://www.fs.usda.gov/coconino).

Proceedings

Presenters are encouraged to publish their work in an online proceedings that will be hosted by the Museum of Northern Arizona (Musnaz.org) and the Springs Stewardship Institute (Springstewardship.org). A deadline for submissions has yet to be set but will likely be in late Fall 2018. For more information please email Larry Stevens at Larry@springstewardship.org.

Maps

The following maps of Flagstaff are provided for pre and post event reference. There are numerous mapping apps, maps, and other references that should be helpful for your visit.



FLAGSTAFF ATTRACTIONS — POINTS OF INTEREST

1. Flagstaff Visitor Center and Amtrak Train Station*
2. The Aquaplex
3. Babbitt Brothers Building*
4. Buffalo Park
5. Bushmaster Park
6. Coconino County Courthouse*
7. Continental Country Club and Elden Hills Golf Course
8. Flagstaff Airport
9. Flagstaff Chamber of Commerce
10. Flagstaff City Hall
11. Flagstaff Convention and Visitors Bureau Administration Office*
12. Flagstaff Main Library
13. Flagstaff Mall and The Marketplace
14. Flagstaff Medical Center
15. Flagstaff Police Department
16. Fort Tuthill County Park
17. Foxglenn Park
18. Greyhound Bus Depot
19. Heritage Square
20. Jay L. Lively Activity Center
21. Historic 1890 Lumberyard*
22. McMillan (Bank) Building*
23. McMillan Mesa Park
24. McPherson Park
25. Hotel Monte Vista*
26. Mountain View Park
27. NAU Walkup Skydome
28. Orpheum Theater*
29. Sawmill County Park
30. Thorpe Park
31. Thorpe Park Softball Complex
32. Weatherford Hotel*
33. Wheeler Park

*Historic Downtown Landmark

FLAGSTAFF VISITOR CENTER

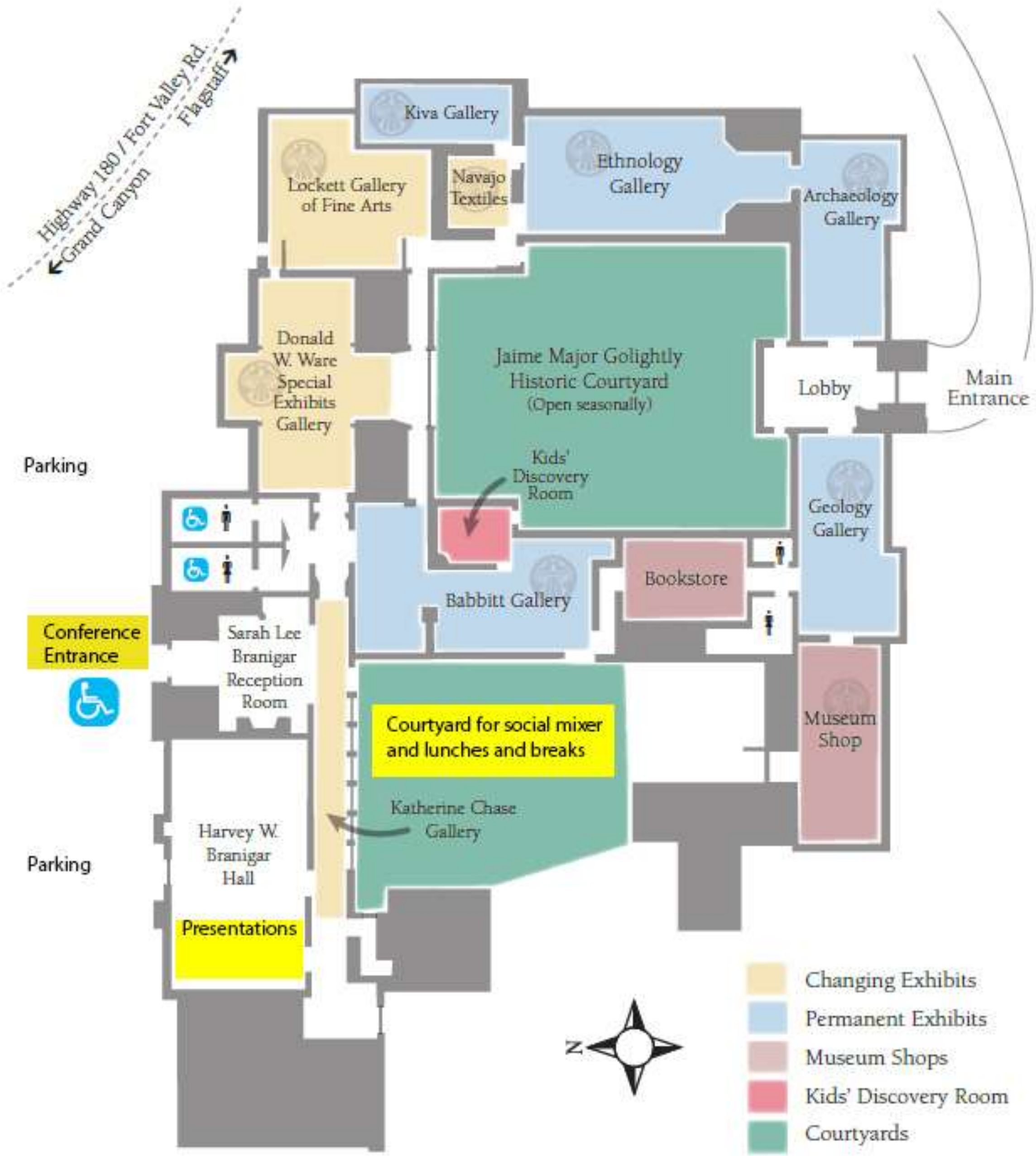
One E. Route 66, Flagstaff, AZ 86001 | 800.842.7293 | 928.213.2951 | visitorcenter@flagstaffaz.gov

Open Monday-Saturday 8 a.m.-5 p.m., Sunday 9 a.m.-4 p.m. Closed Thanksgiving, Christmas and New Year's Day.

flagstaffarizona.org VisitFlagstaff FlagstaffArizona

rev 5/14

The symposium entrance to the Museum of Northern Arizona (entrance facing the parking lot and highway)



A map of the Museum of Northern Arizona with pertinent areas for the symposium highlighted in yellow.

Schedule of Events

All events take place at the main building of the Museum of Northern Arizona on Highway 180 three miles North of downtown Flagstaff. All lunches and the social mixer will take place in the courtyard. Technical sessions and keynotes will take place in the Branigar-Chase Auditorium. Please use the entrance nearest the highway for all events.

Event/Title	Presenter	Affiliation	Time
June 4th			
Registration			4:00 - 5:30 pm
Mixer and Registration			5:00 - 8:00 pm
June 5th			
Registration and Presentation Submittal			8:00 - 9:00 am
Opening comments	Carrie Heionen	Director, Museum of Northern Arizona	9:00 - 9:10 am
Keynote - Springs Ecosystem Ecology and Stewardship: History and Future	Larry Stevens	Springs Stewardship Institute	9:10 - 9:30
Springs flows to restore surface water features post disturbance - Shinumo Creek, Grand Canyon	Edward Schenk	Springs Stewardship Institute	9:30 - 9:50
Break			9:50 - 10:10
Keynote -Consequences of Tamarisk Leaf Beetle (DIORHABDA spp.) Biocontrol in Southwestern Spring and Streamside Riparian Habitats	S.W. Carothers	SWCA Environmental Consultants	10:10 - 10:40
Geologic Subsidies Drive High Productivity in Volcanic Spring-Fed Streams	Carson Jeffres	UC Davis	10:40 - 11:00
Determining springs biodiversity using high resolution eukaryote ribosomal gene sequencing - Ash Meadows NWR	Andrew Martin	University of Colorado	11:00 - 11:20
Genetic population structure in an arid landscape: a comparative study of Chihuahuan Desert invertebrates	Ashley Walters	Miami University (Ohio)	11:20-11:40
Using phylogeography to inform conservation of desert spring invertebrates	David Berg	Miami University (Ohio)	11:40 - 12:00 pm
Lunch			12:00 - 1:20
Keynote - The Demise of Springs Ecosystems: Who's to Blame?	Larry Stevens	Springs Stewardship Institute	1:20 - 1:50 pm
Defending groundwater dependent ecosystems: 2 case studies	Patrick Donnelly	Center for Biological Diversity	1:50 - 2:10
Values, Threats, and Solutions to Protect the Verde	Gary Beverly	Sierra Club	2:10 - 2:30
Where is the spring? Centuries of searching for water at Mesa Verde	Tova Spector	Mesa Verde National Park	2:30 - 2:50
Collaborative Springs Restoration Case Study on the North Rim of the Grand Canyon	Cerissa Hoglander	Grand Canyon Trust	2:50 - 3:10
Break			3:10 - 3:30
Keynote -The Invisible Pulses and Pathways for Ecosystem Health - Inconstant Groundwater Flow, Ephemeral Research Funding, and Fluctuating Public Perceptions	David Kreamer	University of Nevada - Las Vegas	3:30 - 4:00
Hydrogeology of springs in the northern Great Basin in Oregon	Henry Johnson	U.S. Geological Survey	4:00 - 4:20
A remote-sensing approach to assess climate-change vulnerability in spring-dependent ecosystems	Jennifer Cartwright	U.S. Geological Survey	4:20 - 4:40
Springs in the Crooked River Basin, Oregon: Hydrogeologic setting, ecology, and management	Zach Freed	The Nature Conservancy	4:40 - 5:00
Closing Day 1 Remarks	John Spence	National Park Service	5:00 - 5:05 pm

June 6th			
Event/Title	**Presenter**	**Affiliation**	**Time**
Registration and Presentation Submittal			7:30 - 8:00 am
Keynote - Landscape conservation planning for springs management and restoration	Abe Springer	Northern Arizona University	8:00 - 8:30 am
Citizen Science to protect and restore springs and wetlands of the Southwest	Jeff Depew	EarthDesigns LLC	8:30 - 8:50
Inventorying springs for restoration prioritization - Madrean Archipelago	Sami Hammer	Sky Island Alliance	8:50 - 9:10
Springs and Springs-Dependent Species of the Colorado River Basin, Southwestern USA	Jeff Jenness	Springs Stewardship Institute	9:10 - 9:30
Citizen monitoring of springs value to wildlife in Madrean landscape linkages and other focal areas	Scott Wilbor	Sky Island Alliance	9:30 - 9:50
Break			9:50 - 10:10
Geomorphological Influences on Physical and Biological Characteristics of Springs Ecosystems, Grand Canyon Ecoregion, Southwestern USA	David Sinclair	Northern Arizona University	10:10 - 10:30
Developing tools to secure water for springs in the Sky Islands	Louise Misztal	Sky Island Alliance	10:30 - 10:50
Occurrence and characteristics of groundwater-dependent ecosystems on National Forests and Grasslands: results of recent inventories	Kate Dwire	U.S. Forest Service	10:50 - 11:10
National Park Service springs monitoring protocols - Mojave	Jennifer Bailard	National Park Service	11:10 - 11:30
Lunch			11:30 - 1:00pm
Pitfalls, potholes, and reinvented wheels on the road to springs data management	Jeri Ledbetter	Springs Stewardship Institute	1:00 - 1:20 pm
Townhall Discussion: The current state of springs monitoring and where do we go from here	Louise Misztal	Sky Island Alliance	1:20 - 2:20
Break			2:20 - 2:40
Quantifying the effect of springs on tree-growth	Louise Fuchs	University of Perpignan Via Domitia	2:40 - 3:00
Bryophytes Associated with Springs in the American Southwest	John Spence	Glen Canyon National Recreational Area	3:00 - 3:20
Failings in Navajo Sedge monitoring and recovery	Glenn Rink	Far Out Botany	3:20 - 3:40
Terrestrial Gastropod Biogeography in the Grand Canyon Ecoregion, Southwestern USA	Eric North	All Things Wild Consulting	3:40 - 4:00
Spring-Hunting Strategy and the Diversity of Springs in Minnesota	Greg Brick	Minnesota Dept. of Natural Resources	4:00 - 4:20
Wildlife interactions at Great Basin springs	Randy Larsen	Brigham Young University	4:20 - 4:40
Closing remarks	Larry Stevens	Springs Stewardship Institute	4:40 - 5:00

Abstract for the townhall style discussion

1:20pm to 2:20pm on day 2 of the symposium

The Current State of Springs Monitoring and Where We Go From Here

Louise Misztal[1] Samantha Hammer[2] Larry Stevens[3] and Jeri Ledbetter[4]

[1] Sky Island Alliance, 406 S 4th Ave Tucson, AZ, louise@skyislandalliance.org: **Presenter**

[2] Sky Island Alliance, 406 S 4th Ave Tucson, AZ, sami@skyislandalliance.org

[3] Spring Stewardship Institute, 3101 North Fort Valley Road, Flagstaff, larry@springstewardship.org

[4] Spring Stewardship Institute, 3101 North Fort Valley Road, Flagstaff, jeri@springstewardship.org

This one hour session will allow for discussion and debate about the state of springs monitoring protocols and methodologic needs for future springs stewardship and restoration.

Approaches currently used for springs monitoring in the Sky Island Region of the southwestern United States and northern Mexico, and the state of Arizona, range from a newly developed phone app for citizens to use while hiking, to long-term rigorous monitoring protocols utilized by the National Park Service Monitoring Networks. Managers desire to understand how springs are changing over time and between years, how intervention actions including restoration is achieving conservation/restoration goals, and how to know when tipping points have been reached. Monitoring is hampered by limited and often short-term funding. There are several citizen science monitoring approaches recently piloted in Arizona (Sky Island Alliance's Adopt-a-Spring program and development of a phone app by Wildlands Network and the Spring Stewardship Institute), as well as long-established n-depth approaches such as those used by the National Park Service Monitoring Networks. Managers have a diversity of questions they seek to answer and knowledge they wish to gain by monitoring. To facilitate manager's understanding of a range of monitoring approaches, we will host an interactive session for practitioners to share their current monitoring approaches, articulate key techniques, potential pitfalls and monitoring needs for springs. Session outputs will inform development of a workbook/tool to support selection and deployment of different monitoring approaches based on available resources, monitoring questions, and other factors identified by managers themselves as being key to their decisions.

Presentation abstracts – alphabetically order

National Park Service Springs Monitoring Protocols – Mojave Desert Inventorying And Monitoring Program

Jennifer Bailard

Mojave Desert Network Inventory and Monitoring Program, National Park Service

601 Nevada Way, Boulder City, Nevada 89005 United States jennifer_bailard@nps.gov

The Mojave Desert Network Inventory and Monitoring Program (MOJN I&M) is one of 32 ecoregional networks established by the National Park Service to monitor the status and trends of natural resources, including springs. MOJN I&M currently monitors springs at five park units throughout the Mojave Desert, including Death Valley National Park, Joshua Tree National Park, Mojave National Preserve, Lake Mead National Recreation Area, and Grand Canyon-Parashant National Monument. We implement three spring monitoring protocols across these park units: (1) The Desert Springs protocol monitors a rotating panel of 233 smaller springs and focuses on the availability and seasonality of surface water at these springs, as well as water quality where surface water is present. (2) The Selected Large Springs protocol monitors 12 larger springs chosen by park resource managers for their hydrological and ecological importance. These springs are more frequently and intensively monitored for continuous discharge, water quality, and benthic macroinvertebrates. (3) The Spring Vegetation protocol monitors 18 springs chosen by park resource managers. These springs are intensively monitored at the species level for changes in plant community composition, distribution, and abundance. This presentation will include an overview of our three spring monitoring protocols, including a discussion of field methods and preliminary data.

Using Phylogeography to Inform Conservation of Desert Spring Invertebrates

David J. Berg[1], Nicole E. Adams[2, 3], Kentaro Inoue[2, 4], Ashley D. Walters[2]

[1]Department of Biology, Miami University, Hamilton, OH 45011, bergdj@miamioh.edu: ***Presenter***

[2]Department of Biology, Miami University, Oxford, OH 45056

[3]Present address: Department of Biological Sciences, University of Southern California, Los Angeles, CA 90089

[4]Present address: Natural Resources Institute, Texas A&M University, College Station, TX 77843

The use of molecular genetic tools has greatly improved our understanding of the biodiversity of organisms in threatened environments. A number of studies have identified desert springs as hotspots of aquatic biodiversity because of the presence of cryptic and microendemic species. We used a phylogeographic framework to quantify genetic variation in amphipods of the genus *Gammarus* that occupy 16 springs in the northern Chihuahuan Desert of west Texas and southeastern New Mexico. This approach allowed us to examine the evolutionary forces that promoted diversity, while also providing information that was critical to conservation agencies and NGOs. Sequencing of mitochondrial and nuclear genes revealed the presence of two evolutionarily independent lineages of *Gammarus* in this region that shared a most-recent-common-ancestor ~66 million years ago (MYA). One lineage consisted of a radiation from the Gulf of Mexico ~28-16 MYA, while the second lineage was a radiation from northerly freshwater ancestors ~5-2 MYA. Allopatric speciation in each lineage was driven by paleo-geological, hydrological, and climatic events followed by isolation, which promoted genetic drift and local adaptation. Each spring system contains an endemic *Gammarus*, suggesting a total of 8-10 species in the region. Three described species are currently federally listed as endangered, a fourth has just been described, and 4-6 additional species await description. Microsatellite and morphological analyses support the DNA sequencing data providing further evidence of geographically distinct species. These patterns of variation occur in other taxa as well. Using DNA barcoding approaches, we find undescribed and/or endemic species in a wide variety of spring invertebrate taxa including amphipods in the genus *Hyalella,* several groups of snails, and flatworms. Our results provide information that is critical to managers of these unique aquatic habitats, many of which are threatened with destruction due to human demands for water and accelerating rates of climate change.

Spring-Hunting Strategy and the Diversity of Springs in Minnesota

Greg Brick

Gregory.brick@state.mn.us
Minnesota Department of Natural Resources
500 Lafayette Road, Saint Paul, MN 55155 USA

The Minnesota Spring Inventory (MSI) was established by the DNR in 2014 and funded by the LCCMR. Protecting trout and rare plant habitat were major motivations. Judging from neighboring Wisconsin's spring inventory (1956-1962) we expected about 15,000 springs for the proportionately larger area of Minnesota and are now up to 4,500 springs. The Minnesota protocol, modified from DRI (2002) and SSI (2011) protocols, records springs down to 1 gpm.

LIDAR proved the most valuable tool for spring-hunting. A LIDAR tilepack is made in ArcGIS and exported to an iPad tablet. At each spring, GPS location is captured along with a variety of attribute data, with photo, and remotely uploaded. Water parameters are measured where spring flow is sufficient to use probes. While ecosystem data is collected, point of discharge, rather than sphere of discharge, classification, is employed. Citizen science, involving submission of spring locations from cellphones, is promoted, but this data must be verified by DNR personnel.

Minnesota was divided into the following 6 spring-hunting provinces, focusing more on public than private lands. Apart from the first one, the state was largely uncharted territory when MSI began mapping:

The southeastern karst, where about 2,600 springs had already been mapped since the original Surber survey (1918-1920).

The Minnesota River passes from prairie to deciduous forest, allowing us to study springs in relation to climatic and ecological gradients.

The St. Croix River forms much of the eastern border of Minnesota, paralleled by Glacial Lake Lind, whose prominent escarpment contains a sand-clay seepage contact. Whereas springs emanate from Paleozoic sandstones along the southern, downstream, half of the river.

The abandoned sand & gravel beachlines of Glacial Lake Agassiz, roughly paralleling the western border of Minnesota, are associated with calcareous fens.

On the rugged North Shore of Lake Superior the largest springs were not found along trout streams as had been expected, but on the abandoned sand & gravel beachlines of Glacial Lake Duluth, above present lake level.

While Minnesota has more than 10,000 lakes, far fewer are spring-fed. In the Lake District, lakes such as Shingobee, are ringed with littoral springs.

Consequences of Tamarisk Leaf Beetle (*Diorhabda* Spp.) Biocontrol in Southwestern Spring and Streamside Riparian Habitats

Steven W. Carothers
Research Associate
Museum of Northern Arizona[1]

Species of the non-native shrub/tree *Tamarix* were first introduced into the U.S. in the early 1800s as an ornamental, then it became a popular erosion control agent, and by the early 1900s it had proliferated out-of-control and become a recognized and generally reviled invasive species. Since its introduction, *Tamarix* and its two-dominant species, *T. ramosissima* and *T. chinensis* and their hybrids have become a naturalized part of the landscape and are commonly found at springs and stream courses from near sea level to over 2500 m elevation. In 2001 the Department of Agriculture (DOA) unveiled and released an astonishingly effective biocontrol agent, the tamarisk leaf beetle *Diorhabda* spp. This biocontrol effort can be perceived as either an environmental disaster of major consequences to southwestern riparian and spring wildlife populations or celebrated as an example of astute biological ingenuity in fighting invasive species. Until the exotic beetle began its repeat defoliation the *Tamarix*-dominated association provided a unique and remarkably productive habitat type for native wildlife. A review of over 50 wildlife-focused publications demonstrates that *Tamarix*-dominated naturalized habitat supports more avian species than the native species-dominated habitats. Of a total of 140 species of lowland nesting birds in the southwestern United States normally found during the spring and summer months, 110 have been recorded in *Tamarix*-dominated, 100 in mesquite, 79 in cottonwood-willow and 66 in mixed deciduous habitat types. Now, In the shadow of the rapid spread and largely unanticipated success of the *Diorhabda* biocontrol, *Tamarix* is on a large-scale trajectory of decline. This has significantly reduced breeding habitat and cover for many species that have adapted to *Tamarix*, such as the endangered Southwestern Willow Flycatchers (*Empidonax tralii extimus*) and several other species of obligate riparian vertebrates. While biocontrol appears to be satisfying the long-desired eradication of this invasive species much more quickly than expected, after almost two decades of beetle activity within the thousands of acres of dead and dying *Tamarix*, recolonization of the land is almost exclusively limited to a mixture of native and non-native grasses and herbaceous cover with the conspicuous absence of woody species. Thus, at least in the short-term, the biocontrol effort has resulted in the loss of significant acres of wildlife-producing habitat without replacement or adequate DOA plans for revegetation. Defoliated spring sites are likely to be some of the first areas where active habitat restoration efforts will result in successful re-establishment of native obligate riparian woody vegetation.

A Remote-Sensing Approach to Assess Climate-Change Vulnerability in Spring-Dependent Ecosystems

Jennifer Cartwright[1] and Henry Johnson[2]

[1]U.S. Geological Survey Lower Mississippi-Gulf Water Science Center, 640 Grassmere Park, Suite 100, Nashville, TN 37211, jmcart@usgs.gov, ***Presenter***

[2]U.S. Geological Survey Oregon Water Science Center, 2130 SW 5th Avenue, Portland, OR 97201, hjohnson@usgs.gov

Although springs have been suggested as possible ecohydrologic refugia from climate change, some springs may be vulnerable to warming and drought intensification, especially those that depend on recent precipitation or snowmelt for recharge. Effective conservation of spring-dependent ecosystems—and the biodiversity they support—requires empirical approaches to assess resilience of springs to water cycle changes. Unfortunately, many springs lack hydrologic records of adequate temporal extent and resolution to characterize resilience. To help fill these data gaps, remote sensing can be used to characterize seasonal and inter-annual changes in vegetation condition and moisture availability in spring-dependent ecosystems. The U.S. Geological Survey has used Normalized Difference Vegetation Index (NDVI) from Landsat imagery to (1) develop methods to delineate surface-moisture zones (SMZs) in the vicinity of certain spring types (i.e., helocrene, hypocrene, and hillslope springs) and (2) characterize the relative resilience or vulnerability of these SMZs to inter-annual changes in water availability. For 39 clusters of 172 springs in a sage-steppe landscape in southeastern Oregon, USA, seven NDVI-based indicators of resilience were developed, synthesized, and examined in relation to topographic and hydrologic characteristics. SMZs delineated using temporal integration of NDVI were generally located immediately downgradient of springs and/or along riparian areas of spring-fed streams. Seven NDVI-based indicators of SMZ resilience to inter-annual changes in water availability were synthesized using Principal Components Analysis to derive an overall metric of SMZ resilience, which accounted for 66% of total variance. This overall resilience metric was positively correlated with SMZ elevation, slope, mean annual precipitation, degree of topographic shading, and with the number of associated springs. Persistent snowbanks upgradient of several high-resilience SMZs suggested a possible source of steady recharge throughout the growing season. This remote sensing approach could be combined with field assessments of spring discharge, hydrogeology, and groundwater age to help identify spring-fed wetlands that are most likely to serve as hydrologic refugia from climate change.

Using Citizen Science, Education and Community Involvement to Preserve, Protect and Restore Springs and Wetlands of the Southwest

Jeff Depew

EarthDesigns, LLc.; Professional Wetland Scientist jcdepew@earthlink.net

Springs and wetlands of the Southwest are remarkable habitats that support a much larger ecoregion. In the Southwest these areas are ‘jewels’ that hold precious water and are ‘natural areas’ that host an astounding biodiversity. With the appropriate restoration of native plants and wetland species, as well as thoughtful ecological planning and management; these areas become an oasis for wildlife, an educational teaching tool, a source for community involvement and areas of ongoing research. They are the ‘migratory waystations’ and ‘postage stamp habitats’ of the Southwest.

This talk will show, with specific examples, how these areas can and need to be protected and restored, as well as maintained and used by education, community and research-based programs. We will specifically look at the changing climate, water, soils and water use in the restoration of wetland projects in the Southwest. With wise management/stewardship, ecological decision making, planting native plants and the assistance of community partners and students across the region - these areas of water in an arid land can continue to be precious resources.

Defending Groundwater Dependent Ecosystems: 2 Case Studies

Patrick Donnelly[1]

[1] Center for Biological Diversity, Las Vegas, Nevada

Groundwater is one of the most imperiled resources in the southwestern United States, and utilization of the resource is accelerating due to urbanization, agriculture, mining, and other uses. Groundwater dependent ecosystems are of central to supporting the biological diversity of the Great Basin and Mojave deserts, and are at dire risk of drying out and blowing away in the wind due to drawdown of aquifers. This talk will focus on two examples of the Center for Biological Diversity utilizing regulatory, legislative, and legal mechanisms, supported by robust hydrologic and biological science, to defend groundwater dependent ecosystems from destruction due to existing and proposed overexploitation of resources. In eastern Nevada, the Southern Nevada Water Authority has long pursued an enormous groundwater development project intended to send tens of thousands of acre feet of water down a 300 mile pipeline to Las Vegas. And in the Death Valley region, aquifers are in decline due to agricultural and residential overdraft in the Amargosa River Basin. In both instances, interventions are ongoing to stop development which threatens the very existence of groundwater dependent ecosystems.

Occurrence and Characteristics of Groundwater-Dependent Ecosystems on National Forests and Grasslands: Results of Recent Inventories

Kathleen A. Dwire[1] (presenter), Joseph T. Gurrieri[2], Timothy L. Stroope[2], George P. Jones[3]

[1]USDA Forest Service, Rocky Mountain Research Station, kadwire@fs.fed.us

[2]USDA Forest Service, Minerals & Geology Management Groundwater Program; jgurrieri@fs.fed.us; timothylstroope@fs.fed.us

[3]Wyoming Natural Diversity Database, gpjones@uwyo.edu

Inventories of groundwater-dependent ecosystems (GDEs), primarily springs and wetlands, are being conducted on National Forests and Grasslands throughout the USA to determine the distribution and characteristics of these critical natural areas. In 2012, the US Forest Service (USFS) published the Groundwater-Dependent Ecosystems (GDEs) Level 1 Inventory Field Guide, which provided standardized protocols to evaluate a core set of ecological parameters and management indicators at each GDE site, resulting in consistent assessment and characterization of GDEs on public lands administered by the agency. Inventory efforts are frequently collaborative projects among the USFS, state agencies and heritage programs, academic institutions, and non-profit organizations, including the Springs Stewardship Institute (SSI). Data entry into Springs Online, an established database maintained by the SSI, has facilitated the secure archival of the valuable inventory information. The consistent collection of on-site field data, coupled with systematic information management, provides a valuable baseline for effective management, and allows for comparisons of GDE features among different Forest Service units, ecoregions, and climatic regimes. In 2012, the USFS also released the revised Planning Rule, with direction for Forest Plan revision that requires consideration of groundwater resources, indicating the increased recognition of both the ecological importance of GDEs and the pressures on groundwater on public lands.

Here, we present recent findings from inventories conducted on National Forests in Utah, Wyoming, and Colorado, particularly GDE distribution and characteristics relative to elevation, hydrogeology, precipitation regime, geomorphic land forms, and past glaciation activity. We also provide examples of the utility of GDE inventories nationwide in: (1) regional and forest-level assessments of climate change vulnerability; (2) multiscale assessments of carbon storage, instream flow support, and other ecosystem services; (3) locating populations of rare biota that are partially or wholly dependent on GDE wetland and/or spring habitats; (4) identifying the need and options for improved management, with recommended actions specified in revised forest plans; (5) improving capability to assess and predict threats to groundwater resources.

The stewardship of GDEs is improved through increased understanding of their landscape-level distribution and condition, which is best achieved through collaborative inventories using consistent methods and systematic data managment.

Springs In The Crooked River Basin, Oregon: Hydrogeologic Setting, Ecology, And Management

Zach Freed[1], Allison Aldous[2], and Marshall Gannett[3]

[1] The Nature Conservancy, 999 SW Disk Drive, Bend OR 97702, zach.freed@tnc.org: ***Presenter***
[2] The Nature Conservancy, 821 SE 14th Ave, Portland OR 97214
[3] U.S. Geologic Survey Oregon Water Science Center, 2130 SW 5th Ave, Portland OR 97201

The Crooked River Basin in central Oregon has a high concentration of mapped springs on public land, where livestock utilize grazing allotments during the summer. Two types of springs commonly developed for livestock use across the state are rheocrene springs and fens, and each spring is associated with distinct wetland and aquatic communities. Species utilizing rheocrene spring habitat, such as the imperiled (S2) Pristine pyrg spring snail, are found near the spring orifice or along the springbrook. Fen species, particularly bryophytes such as the imperiled (S2) *Tomentypnum nitens*, are dependent upon a consistently shallow water table and peat development. Of 180 springs surveyed from 2013 – 2015 in the Crooked River Basin, 95% of diffuse-discharge springs and 79% of rheocrene springs were impacted by livestock and development. A spring development often results in all water being diverted from the groundwater-dependent ecosystem to a cattle trough, allowing easy access for livestock. In rheocrene springs, developments eliminate spring orifice and springbrook habitat. In fens, developments lower the water table, which can compact the peat soils and degrade the fen habitat. The Nature Conservancy, in collaboration with the U.S. Forest Service, is testing the efficacy of retrofitting existing spring developments to provide sufficient water for livestock while also protecting the groundwater-dependent ecosystems. Two retrofit designs were created: one each for rheocrene spring developments and fen spring developments. The rheocrene retrofit features modified springbox outflow piping intended to continuously maintain flow to the spring orifice and springbrook. The key component of the fen retrofit is a modified springbox that maintains the water table elevation above a user-defined threshold. Two pilot retrofits were installed at Sand Spring and Horse Fen in the Ochoco National Forest within the Crooked River Basin during Fall 2016. We hypothesize that retrofitting the spring developments will result in the re-establishment of groundwater-dependent vegetation and macroinvertebrates in the historical spring orifice at Sand Spring and the peat wetland at Horse Fen. This presentation will discuss the engineering objectives, ecological goals, and preliminary monitoring results of the pilot study.

Quantifying the Effect of Springs on Tree-Growth

Louise Fuchs[1], Lawrence E. Stevens[2] and Peter Z. Fulé[3]

[1] University of Perpignan, Perpignan, France, louise-fuchs@neuf.fr _*Presenter*
[2] Springs Stewardship Institute, Museum of Northern Arizona, Flagstaff, AZ, US
[3] Northern Arizona University, Flagstaff, AZ, US

A large number of studies have been held on tree rings all over the world. Dendrochronology was invented in the early 1920's in Arizona, USA, and is defined as being the study of annual tree rings, analyzing the changes in the rings' growth through time. Dendrochronology applications' field has been growing since then, and today many studies such as fire management, trees demography and even geological studies depend on it.

Dendroclimatology uses tree rings to infer past climatic conditions. Humidity affects tree rings' growth, and precipitation is agreed to be one of the main factors infering on the tree rings' width. However, springs' effect on tree growth has never been documented.

We studied growth responses of *Pinus Ponderosa* trees to springs' flow variability across the South-West of the United States on various slopes and elevations. We gathered a total of 50 tree cores at 8 different spring locations around Flagstaff, Arizona. We wanted to show that springs affect trees situated next to them, and even that the springs' flow could be seen in the growth records. The soil characteristics were similar for trees near and away from springs, so that soil effect could be neglected. We compared the rings' width of each specimen to the characteristic patterns of dry (marker) and wet years of chronologies, compiled previously from various trees near Flagstaff. After drying, mounting and dating the cores, we calculated the mean sensitivity of each sample and compared them together.

We hypothesized that spring flow would covary closely and positively with tree growth - and thus tree rings width, and that trees next to springs would be more complacent to dry years. We also predicted that growth sensitivity to springs' perenniality would be higher at steeper slopes.

Inventorying Springs for Restoration Prioritization - Madrean Archipelago

Sami Hammer
Sky Island Alliance
406 S 4th Ave, Tucson, Arizona 85701 United States sami@skyislandalliance.org

Since 2012, Sky Island Alliance has worked to inventory and assess springs in the Sky Island region, also called the Madrean Archipelago. The need for spring ecosystem inventory and restoration was identified at regional climate change adaptation workshops SIA developed with numerous partners and convened in 2010 and 2011. A key strategy identified to address this was to inventory springs in priority watersheds to gather basic information on condition, species presence, and management status. To date, we have assessed over 300 springs in 18 mountain ranges in Arizona and Sonora with the help of thousands of hours donated by volunteers. Most recently, we have focused on how fire affects springs, collecting water rights information, and surveying for spring snails. I will share some of what we have learned from these assessments, updates on what we have accomplished, and discuss areas that still lack data.

Collaborative Springs Restoration Case Study on the North Rim of the Grand Canyon

Cerissa Hoglander

Grand Canyon Trust (Flagstaff, Arizona)

Water resources in the arid Southwest are inherently contentious given the multiple uses and tendencies for overallocation. Threatened by overuse and sensitive to disturbance, springs are among the most imperiled waters across this region. Springs ecosystems are biodiversity hotspots, culturally significant sites, and key components of overall landscape health. These ecosystems provide critical water resources and, on public lands, are often shared among human, wildlife, and livestock uses. Despite their importance, efforts to understand springs conditions, threats, and appropriate management approaches are still in their early stages. Many of the springs across the Colorado Plateau are impacted by pollution, trampling, non-native species invasions, and water diversion developments. With increasing water demands and intensifying drought driven by climate change, efforts to protect and restore springs are paramount.

Central to the Grand Canyon Trust's mission is the protection and restoration of the Colorado Plateau. Through collaborative efforts to restore springs we not only have an opportunity to protect water resources and improve landscape health under increasingly arid conditions, but also an opportunity to build partnerships among stakeholders and to engage the broader public in conservation advocacy. We present case studies of our volunteer-powered work to gather information on and restore four developed but significant springs on public lands in the greater Grand Canyon watershed. Through collaboration with land and wildlife managers, springs experts, dedicated volunteers, and the local rancher, our work thus far has improved native plant dominance and wildlife water access while balancing livestock water use. The success of these collaborative efforts is further demonstrated through ongoing monitoring and over 2,000 hours of on-the-ground volunteer engagement. It has also led to the expansion of committed efforts among many partners to advance springs assessment, restoration, and protection across a broader landscape. We hope that these efforts can serve as pilot studies for restoration approaches at developed springs and can help forward the planning and implementation of collaborative conservation across the Colorado Plateau.

Geologic Subsidies Drive High Productivity in Volcanic Spring-Fed Streams

Carson A. Jeffres[1], Andrew L. Nichols[1], Robert A. Lusardi[1], Michael L. Deas[2], Jeffrey F. Mount[3], Peter B. Moyle[1], Randy A. Dahlgren[1]

[1] University of California, Center for Watershed Sciences – Davis, California 95616, USA. cajeffres@ucdavis.edu (Carson Jeffres, Presenter)

[2] Watercourse Engineering, Inc. – Davis, California 95616, USA.

[3] Public Policy Institute of California – San Francisco, California 94111, USA.

Critical habitats for cold-water species in lotic ecosystems are anticipated to diminish as global climate change reduces summertime availability of cold water in streams. A hitherto overlooked exception is volcanic spring-fed streams that occur extensively in volcanic terrains throughout the Pacific Ring of Fire. Results of our interdisciplinary study in northern California demonstrate that these streams produce reliably cool summer baseflow and geologically-derived nitrogen and phosphorous to drive exceptional aquatic ecosystem productivity and resiliency, as well as a metabolic advantage for tolerating higher water temperatures. For example, steelhead trout (*Oncorhynchus mykiss*) take advantage of these abundant food resources and stable hydrologic conditions to grow faster and larger (6-fold greater mass) than individuals from an adjacent runoff-dominated river. These spring-fed, nutrient-rich habitats are likely to be exceptionally important for conserving cold-water species impacted by global climate change, and should be considered high value conservation and restoration targets.

Springs and Springs-Dependent Species of the Colorado River Basin, Southwestern USA

Jeff Jenness and Lawrence E. Stevens

Springs Stewardship Institute

Museum of Northern Arizona

Jeff@SpringStewardship.org; Larry@Springstewardship.org

The hydrogeology of the Colorado River basin (CRB) has been intensively studied because it is the primary water source for more than 40 million people in southwestern North America and is famously over-allocated. More than half of the Colorado River, and a critically important percent of its baseflow, is provided by springs; however, springs contribution to flow and ecosystem and biodiversity values, have received little attention in the basin. We studied the distribution of springs and springs-dependent species in the CRB using existing literature and 5,873 recent and historic surveys on 2,910 springs to review the extent of information on springs distribution, ecosystem roles, and goods and services. We find 20,485 springs have been reported in the CRB, and many more likely exist but are unreported. Springs are highly patchily distributed, with highest concentrations in montane and cliff-dominated escarpment settings, and relatively few on valley floors. Certain spring types are closely tied to geophysical province, with hanging garden springs located disproportionally within the Colorado Plateaus, and rheocrenes appearing predominantly in the Basin and Range region. Springs exist widely across elevation, from 0 m to more than 4000 m. CRB springs flows range up to 3,029 L/sec, and in Arizona springs contribute >0.6 km^3 of water, flow that is primarily used to support wildlife and livestock, rural use, and some urban use. We detected several hundred springs-dependent species throughout the basin, primarily invertebrates, fish, amphibians, reptiles, several mammals, and one bird species (southwestern American Dipper, *Cinclus mexicanus*). One site, Montezuma Well, has the highest reported concentration of unique species of any point in North America to our knowledge. Thus, although springs remain biologically and culturally significant and highly threatened, they are poorly mapped, underappreciated, and generally poorly managed. We recommend more thorough inventory, assessment and, where practicable, rehabilitation.

Hydrogeology of Springs in the Northern Great Basin in Oregon

Henry M. Johnson

U.S. Geological Survey Oregon Water Science Center, 2130 SW 5th Avenue, Portland, Oregon 97201, hjohnson@usgs.gov

Drought, climate change, and multiuse management of water resources in southeastern Oregon are driving a new, regional investigation of springs in the area. Springs are often the only available surface-water source for tens of kilometers in the Northern Great Basin, and are important water resources for livestock and habitat for the native flora and fauna. In recent years, the US Forest Service and Bureau of Land Management (BLM) have inventoried many of the larger springs on lands they manage in the region. However, most of the springs across the Northern Great Basin in Oregon are known only as a point on decades-old maps; their existence, current condition, current use, and short- and long-term viability as water resources are unknown.

In 2016, in cooperation with the BLM, the USGS Oregon Water Science Center began an evaluation of springs across 50,000 square kilometers of the Northern Great Basin in Oregon with the goal of providing a regional understanding of the hydrology of these poorly documented, but important features. Our work focuses on understanding the physical hydrology of the spring systems, including geologic and topographic controls on the spring location, discharge volume, and to the extent possible, an understanding of the short- and long-term discharge variability. Field assessments include an on-site evaluation of the geology, documentation of the spring morphology and its geographic setting, measurement of basic field chemistry (temperature, specific conductivity, pH), a discharge measurement, a sample for the analysis of stable isotopes of water, and at selected sites, collection of samples to estimate the residence time. This talk provides an overview of our work to date and a preliminary evaluation of the data we have collected.

The Invisible Pulses and Pathways for Ecosystem Health – Inconstant Groundwater Flow, Ephemeral Research Funding, and Fluctuating Public Perceptions

David K. Kreamer[1]

[1]Department of Geoscience, University of Nevada, Las Vegas, 89154-4010, dave.kreamer@unlv.edu

Springs, seeps, wetlands are often remote and hidden – from physical view and from funding sources. Recent dye tracer tests in the Grand Canyon, Arizona, U.S.A. have shown what scientists have learned in other parts of the world - that groundwater can flow in totally unexpected directions to springs with unanticipated average residence times in the subsurface. In this invisible world of the Grand Canyon, new caves are being discovered with many miles of passage. Likewise pathways and pulses of research funding are often tortuous and periodic. When springs are actually located and measured, often chemical and biological assays are limited. Sticking with the example of the Grand Canyon, analysis of heavy metals is rarely carried out in the sampling of springs, but when those parameters are actually analyzed, their aqueous concentrations are very often above drinking water standards. Arsenic in Grand Canyon spring water is a prime example; from over 4100 historical sampling events throughout the Canyon, arsenic was not even included in analyses 87.0% of the time. When it was measured it was detected 88.4% of the time, and when detected it was above drinking water standards (Maximum Contaminant Level or MCL of 0.01 mg/L) 53.8 % of the time (Kreamer, 2017). Clearly there is a lot going on in subsurface water quality that scientists, because of limited data and resources, are missing.

Many springs, particularly in arid and semi arid lands, are vulnerable to slight changes in water table or piezometric surface elevation which can result from groundwater exploitation and climatic variability. Perennial springs in wetter lands are often no less vulnerable to diminishment or change in quality. The historical record of springs, and documentation of their chemical, biological and physical attributes is, in many locales, sparse or non-existent, (although recent standard methodologies for spring description and inventory have been developed and are revolutionizing spring characterization). In spite of successes, while aquifers overflow to land surface from invisible pathways, financial resources underflow to ecohydrological research. Much of the erratic nature of environmental investigation and support comes from the inconstancy of political direction, evidenced in changing administrative environmental priorities.

Wildlife Interactions at Great Basin Springs

Randy Larsen

5046 LSB, Provo, UT 84602 United States, Brigham Young University

Water both limits and constrains life and is essential for completion of life cycles for a host of organisms. In arid and semi-arid environments, springs provide free or drinking water to wildlife. Availability of drinking water can be a limiting factor for some wildlife species. Large exotic species, such as the horse (Equus caballus), may have a competitive advantage over smaller native species and could exclude them from access to limited water resources. For the past 10 years, we've used remote cameras placed at springs in Utah's Great Basin desert to test hypotheses about how wildlife interact with other species at water sources. Wildlife detected in imagery taken at springs include 40 species of birds and 13 species of mammals. Of the images of mammals, 79% contained horses. Horses were associated with decreased richness and diversity of native species at water sources. Furthermore, native species had fewer visits and spent less time at water sources frequented by horses. For the two native ungulates (mule deer, Odocoileus hemionus and pronghorn, Antilocapra Americana) in our study area, we also found that both species used water sources less often where horse activity at water sources was high, indicating that spatial avoidance occurred. Further, we observed significant differences in peak arrival time for pronghorn, but not mule deer at horse-occupied sites versus sites where horses were absent or uncommon, indicating that temporal avoidance may be more important for pronghorn than mule deer. Our findings indicate that feral horses can further constrain access to an already limited resource for native species in a semi-arid environment. These findings form the basis for a new initiative to sample several hundred springs in Utah's west desert and assess their condition.

PITFALLS, POTHOLES, AND RE-INVENTED WHEELS ON THE ROAD TO SPRINGS INFORMATION MANAGEMENT

Jeri Ledbetter

Museum of Northern Arizona, Springs Stewardship Institute, jeri@springstewardship.org

Springs ecosystems, among the most biologically diverse of habitats, are poorly understood and afforded little protection. Increased recognition of these fragile resources has led to growing interest among agencies, NGOs, and independent researches who have begun to develop protocols, and collect and compile data. Database management systems (DBMS) have primarily included Microsoft Excel and Access, and GIS. Over several years, the Springs Stewardship Institute has imported many of these datasets into Springs Online, a collaborative online database in an effort to serve data that cross political and managing agency boundaries. This process is challenging due to the wide variety of data collection methods, ranging from standardized, published protocols to non-standardized or poorly considered methods. Some data have been collected on field sheets, but not entered. When entered at all, researchers primarily have used the readily-available Excel. However, spreadsheets allow conflicting or ambiguous entries, inconsistent spelling, and incompatible data (e.g., differing units). The result does not provide data that can be analyzed (e.g., at what elevation range does a particular species occur?). Some data have been entered into a GIS, which is a much more time consuming way to enter and requires a higher skillset. Further, without proper design and forethought, data analysis may not be possible (e.g., entering numeric flow values into a text field). One geodatabase concatenated species lists into one text field with mis-spellings and inconsistent entries (mixing symbols, common names, and scientific names). Some relational DBMS, (e.g., Microsoft Access) have not employed best practices, and do not provide easy, consistent data entry or robust reporting capability. Many agencies, NGOs, and independent researchers want to develop their own protocols and/or design separate databases rather than use Springs Online, a platform that is already available. This presentation will address the most common challenges that SSI has encountered with managing datasets, and offers solutions to assure that investment in field data collection results in accurate and meaningful information.

Developing Tools to Secure Water for Springs in the Sky Islands

Louise Misztal[1] and Samantha Hammer[2] Rachel O'Connor[3], Ashley Hullinger[4]

[1] Sky Island Alliance, 406 S 4th Ave Tucson, AZ, louise@skyislandalliance.org: **Presenter**

[2] Sky Island Alliance, 406 S 4th Ave Tucson, AZ, sami@skyislandalliance.org

[3] AMP Insights, PO Box 1892, Beaverton, OR 97075, rachel@ampinsights.com

[4] UA Water Resources Research Center, 350 N Campbell Ave,Tucson, AZ 85719, hullinger@email.arizona.edu

The Sky Island Region of the southwestern United States and northern Mexico boasts 2,000 mapped springs in the U.S. portion alone. Thanks to investments from the applied science program of the Desert Landscape Conservation Cooperative and Reclamation WaterSMART grants, regional knowledge about springs has increased dramatically in the last 6 years, new collaborative efforts to conserve and restore spring have emerged, data is readily available on individual springs to inform management and new guidance has been developed on surveying and restoring springs. The growing knowledge of spring ecosystems and interest in their management has led to concern from managers (federal, state, local and private) that these systems are offered limited policy protection disproportionate to their ecological significance. Additionally, there is insufficient knowledge on how hydrological, spatial configuration, and jurisdictional overlays intersect with corresponding standards and policy tools to influence conservation and restoration priorities among a selection springs and stream resources available for management action. To address these concerns, we are working to develop a toolbox of enabling conditions for springs and streams to help managers prioritize conservation and restoration locations, and synthesizing springs monitoring approaches to develop guidance on aligning monitoring questions with possible approaches. The tool is being developed in partnership with agency personnel, land managers, tribal members, and interested stakeholders who are stewarding springs. Outcomes of tool development include 1) an analysis of existing springs sites and watersheds and 2) an exploratory multi-criteria tool for managers to evaluate landscape-scale and site-specific attributes. The springs tool has four focal areas for characterizing spring systems and the surrounding landscape: biophysical attributes; management context; cultural values of the spring and surrounding landscape; and resilience to potential climate change impacts.

Terrestrial Gastropod Biogeography In The Grand Canyon Ecoregion, Southwestern Usa

Eric G. North[1] and **Lawrence E. Stevens[2]**

[1] All Things Wild Consulting, P.O. Box 254, Cable, WI 54821; xcskyr@hotmail.com:
[2] Springs Stewardship Institute, Museum of Northern Arizona, 3101 N. Ft. Valley Rd., Flagstaff, AZ 86001; lstevens@musnaz.org. **presenter**

We studied the biogeography of land Gastropoda in the Grand Canyon ecoregion (GCE) on the southern Colorado Plateau. Literature, museum data-mining, and replicated, randomly stratified sampling at springs and in adjacent upland habitats were used to test whether contemporary range predicted elevation range and mediated local ecological gradient influences on assemblage composition and structure in this 35,000 km2, topographically diverse landscape. Previous researchers reported approximately 287 terrestrial gastropod taxa in the southwestern molluscan assemblage, including 234 native species among 38 genera in 18 families, a fauna dominated by Helminthglyptidae and other large-bodied families and with many locally endemic species. We documented 74 native and non-native land Gastropoda species in 32 genera among 17 families in the GCE (25.8% of the provincial fauna). Stratified random quantitative field sampling at 18 paired springs and non-springs upland habitats across elevation revealed 30 land snail species in 21 genera among 12 families>Land snail densities at desert springs reached 16,679 snails/m^2. Like the GCE assemblage, but in contrast to the provincial assemblage, the field assemblage was strongly dominated (53.3 percent) by widely distributed, small boreal (Rocky Mountain, nearctic, or circumpolar) taxa. We demonstrate a strong overprint of contemporary biogeographic range across elevation, from desert springs into montane forests. The GCE assemblage is a fauna distributed in an inverse latitudinal diversity gradient (iLDG). Although boreal taxon richness, H’ diversity, and assemblage differences between springs and adjacent uplands all decreased with elevation (a pattern expected among LDG assemblages), small-bodied boreal taxa dominated the assemblage across elevation. Land snail biogeography is a dominant factor in assemblage composition across elevation and microhabitat gradients. Conservation of desert springs will disproportionally protect boreal land gastropod biodiversity in the Southwest, but protection of individual springs, microhabitat types, and species are needed to sustainably conserve the southwestern fauna.

Failings in Navajo Sedge Monitoring and Recovery

Glenn Rink[1]

[1]Springs Stewardship Institute, Museum of Northern Arizona, 3101 N Fort Valley Rd, Flagstaff, AZ 86001, faroutbotany@gmail.com: presenter

Navajo sedge (*Carex specuicola*) is a hanging garden specialist. Hanging gardens are islands within a dry, desert landscape that is inhospitable for the species outside of the hanging garden habitats. Many mis-steps have been made along the path to gaining an understanding of the taxonomy, range and abundance of Navajo sedge. 1) Explorers failed to document areas where they searched for the plant, but did not find it, which is critical for understanding the island biogeography of this species. They also failed to adequately document where they had found the plants, making re-visits problematic. 2) Navajo sedge is presently known from: Navajo, Canyon de Chelly, and Natural Bridges National Monuments; it is to be expected in Glen Canyon NRA, w/ its extensive hanging gardens, but specimen review indicates that we haven't found it there yet. GLCA Navajo sedge specimens were mis-identified specimens of golden sedge (*Carex aurea*); others were re-assigned to Utah sedge (*Carex utahensis*), a taxon that was named after Navajo sedge was listed. The same kinds of mistakes were made at many other locations, which led to a skewed understanding of the species' range. 3) Our understanding about the relationships between plants in separate hanging gardens has suffered from unsupported assumptions about what constitutes a "population". 4) We failed to define a repeatable procedure for determining plant abundance at a site. Part of the problem is that Navajo sedge is a rhizomatous perennial. Some (perhaps most) sites may be occupied by just a single plant. Many of these problems have been addressed in the last few years and our improved approaches may result in delisting.

Environmental Characteristics of Great Basin and Mojave Desert Spring Systems

Donald W. Sada and Alexandra D. Lutz
Desert Research Institute, Reno, NV

We report on the environmental characteristics at 2,256 Great Basin and Mojave Desert springs that were inventoried from the late 1980s into 2013. These springs ranged widely in size, water chemistry, and vegetative cover. Median estimated discharged was less than 10 l/min, springbrook length was less than 50 m, water depth was less than 3 cm, and median springbrook width was less than 100 cm. Water chemistry varied from cold to very hot, from low to very high electrical conductance (EC) and dissolved oxygen (DO) concentrations, and ph from moderately low to moderately high. The environment at most springs was relatively moderate with median temperatures near ambient, relatively high EC, pH slightly higher than neutral, and DO was moderate. Median emergent and bank cover generally exceeded 50 and 68 percent, respectively, and fines dominated substrate composition in most springs. Sand, gravel, cobbles, and boulders were relatively scarce.

Approximately 3 percent the springs were disturbed by natural factors, and evidence of human disturbance was at approximately 83 percent of springs. by either diversion, horse, burro, or cattle use, recreation, or dredging, and many springs were degraded by several of these uses Approximately 65 percent were moderately or highly disturbed. Degraded springs were most common on US Bureau of Land Management land, followed by private lands, US Forest Service, then U.S. Fish and Wildlife Service.

Changes in the condition of 265 springs over approximately 20 years found that condition improved in 16 percent, was unchanged in 40 percent, and more degraded in 44 percent of springs. Furthermore, extirpation of 82 populations of 49 rare taxa, and seven extinctions were documented from these springs.

Clearly, existing management is not providing for the ecological health of these systems and new strategies are needed to change an increasing downward trend.

Springs Flows Restoring Surface Water Features Post Disturbance – Shinumo Creek, Grand Canyon

Edward R. Schenk

Springs Stewardship Institute, Museum of Northern Arizona

The influence of groundwater on stream and riparian features is relatively unexplored. This presentation provides a case study of the restorative effects of several large perennial springs on a debris flow impacted Colorado River tributary stream. Shinumo Creek is a relatively high gradient perennial stream (92 m/km) that historically supported native fisheries and a robust riparian habitat. Overland flow occurs during brief intense monsoonal storms during summer months, otherwise almost all flow, including snowmelt, is derived from karstic springs emanating from the Muav Limestone. The Galahad Fire began May 23, 2014, and burned 2484 hectares of ponderosa pine forest in the headwaters of the creek (~10% of the watershed), with a portion burned below the rim on extremely steep slopes. Subsequent monsoonal storms caused two large floods later in the summer: the first was observed to carry substantial charcoal and ash into the Colorado River; the second included a debris flow with a stage approximately 5 m above base. Site visits following the floods found no fish in the mainstem of the creek, a denuded woody riparian zone, and channels severely altered with sequenced scour and fill reaches. Large sections of the channel had in-filled with fine sediments (coarse sand/pebbles) creating braided shallow reaches insufficient for native fisheries. Channel change surveys were conducted in 2015, 2016, and 2017 consisting of streamgage analysis, bedload hydrophones, repeat cross-sections, pebble counts, and repeat photography. Within three years the stream has largely recovered to a pre-disturbance cobble-boulder bed single-thread channel. The majority of channel change occurred during spring snowmelts: a two to three week period of high, sediment poor, flow from springs that effectively flushed the channel re-creating fisheries habitat for the endangered Humpback Chub. Climate change predictions for the region indicate more severe summer monsoon storms and less snowpack in the contributing area. If these predictions come true there will be more frequent disturbance events and less springs contributions to restore perennial channels after debris flows. Effective adaptive management of Grand Canyon perennial surface water resources will require an understanding of springs and regional groundwater processes and their vulnerabilities.

Geomorphological Influences on Physical and Biological Characteristics of Springs Ecosystems, Grand Canyon Ecoregion, Southwestern USA

David A. Sinclair[1], Abraham E. Springer[1], and Lawrence E. Stevens[2]

[1] School of Earth Sciences and Environmental Sustainability, Northern Arizona University, Flagstaff, AZ 86011
[2] Springs Stewardship Institute, Museum of Northern Arizona, 3101 N. Ft. Valley Rd., Flagstaff, AZ 86001

The Grand Canyon Ecoregion (GCE) occupies the Grand Canyon drainage on the southern Colorado Plateau and is a topographically diverse landscape with a wide array of environments and corresponding plant communities. Springs are numerous in the GCE and provide critical sources of water that support many rare, endemic, and some endangered springs-dependent species. We conducted a statistical analysis to distinguish geomorphologic influences on physical and vegetation differences among four regionally common spring types – helocrene wet meadows, hanging gardens, rheocrene flowing springs, and hillslope springs (total N = 350 springs). As in other studies of springs, we detected remarkably high species packing, with 45% of the region's entire flora found in 0.45 km^2 (<0.01% of the landscape).

The four springs types were distinguished by differences in physical characteristics, which in turn were associated with plant community structure and species distributions. Elevation, geochemistry, and geomorphic diversity (i.e., microhabitat features, including substrate composition), differed among springs types and were strongly correlated with plant assemblage characteristics. A unique suite of indicator plant species were associated with each spring type: hanging gardens were characterized by ferns, orchids, and other native species, while hillslope and rheocrene springs supported more generalist species, and helocrenes (which often are heavily grazed) were characterized by non-native species. Multivariate regression analysis identified suites of variables related to springs plant biodiversity, explaining nearly half of the variation in species richness between springs. Microhabitat richness, area, and elevation were most influential factors affecting plant species richness. Although grazing intensity was negatively related to the diversity of non-native plant species found at springs. While this study identified key differences between springs types, springs ecosystems are highly individualistic and expanded inventory is needed to improve understanding of springs biodiversity. Stewardship actions that identify and protect an array of springs across elevation, as well as protecting rare springs types is likely the best way to conserve springs-dependent species across the GCE and throughout the nation.

Bryophytes Associated with Springs in the American Southwest

John Spence

Science & Resource Management Division, Glen Canyon National Recreation Area, PO Box 1507, Page, AZ 86040 USA

Based on collections, field work and published accounts, a preliminary checklist of bryophytes known from springs in the southwestern US, including southern Utah, Arizona, southern Nevada, and southeastern California, is presented. Biogeographic areas covered include the Colorado Plateau, Madrean Sky Islands, Sonoran Desert, and Mohave Desert. The checklist includes 11 liverworts and 80 mosses in 29 families from ca. 250 springs. The distributions of the bryophytes include three principal groups, widespread species, northern boreal-temperate species, and southern Madrean-subtropical species. Several undescribed species new to science are included. Ecologically, mid- to high elevation (>1000 m) springs support the most species, while low elevation hot desert springs generally support few species. Of the total, 46 species (51%) are considered obligate phreatophytes, requiring water most of the year. Species are characterized by their substrate preferences, with the majority of species either calciphiles or generalists, while very few prefer acidic substrates. Due to human development and loss of spring vegetation and discharge alterations throughout the region, many bryophytes are rare and regionally threatened.

Landscape Conservation Planning for Springs Management and Restoration

Abraham E. Springer

School of Earth and Sustainability, Northern Arizona University, Flagstaff, AZ 86005, abe.springer@nau.edu

Springs are places where groundwater discharges at or near the earth's surface under air, water or ice. Springs ecosystems support a wide diversity of species and cultures across all landscapes, some of which are dependent on the specific habitat conditions which occur at the point of emergence of the water. At least thirteen spheres of discharge have been proposed to classify springs ecosystems. Descriptive data exist to demonstrate that a few of these spheres of discharge are statistically significantly different, requiring specific management and restoration needs. Comprehensive inventory and assessment techniques have been developed and used to describe 1,000s of springs ecosystems across Western North America. Springs support the headwaters of most perennial streams, but the location and identification of springs continues to be limited by the adoption of a universal classification system and database. Less than 10 % of the springs on most landscapes have been identified and even fewer have been comprehensively inventoried and assessed. Recent nationwide surveys have estimated the non-market values of springs in wilderness in Grand Canyon National Park. Although springs occupy far less than one % of the area of most landscapes, inventories of springs across landscapes indicate that up to 45 % of all plant species are supported at springs. Common, comprehensive inventory and assessment data collected with multiple different protocols are accessible on the secure, cloud-sourced Springs Online database of the Springs Stewardship Institute. Inventory and assessment techniques have been adapted and adopted by many land and resource management organizations, including many indigenous nations. Techniques developed to assess the condition and risks of springs ecosystems can be used to prioritize stewardship action across landscapes. Stewardship prioritization is an essential component of successful landscape conservation design planning, especially when resources for stewardship are limited. When successfully implemented, landscape conservation planning can assist with sustaining the important ecosystem services that springs support. Predictions of the responses of the ecosystem to climate change should be included in the planning and design process, so resource utilization is optimized. Examples of management and restoration actions based upon landscape level inventory and assessment will be provided for springs across the greater Grand Canyon Ecoregion.

Springs Ecosystem Ecology and Stewardship: History and Future

Lawrence E. Stevens
Museum of Northern Arizona Springs Stewardship Institute
Flagstaff, Arizona; Larry@SpringStewardship.org

Springs are places where groundwater is exposed at, and usually flows from the Earth's surface, with both subaqueous and subaerial expression. Springs are the most productive, biologically diverse, socio-culturally and economically important, and evolutionarily intriguing features of many landscapes, particularly in arid regions. However, they also are among the most threatened ecosystems, being subject to an ever-increasing array of anthropogenic impacts on groundwater and poorly-informed surface land management practices. Springs are geomorphically and ecologically diverse, with 13 identified spheres of emergence (types), each of which may contain a wide array of microhabitats and species assemblages. While springs are generally small ecosystems, springs are likely the most sustainable ecosystems, and can readily be rehabilitated if the supporting aquifer is relatively intact. Our springs symposium in 2000 produced recommendations to improve springs ecosystem science and stewardship. Here I summarize progress over the past two decades in understanding springs ecosystem ecology and biodiversity, and indicate potentially fruitful directions for future research and management. I also review progress in codifying comprehensive springs inventory and assessment protocols and information management, subjects that will be described in more detail in other talks in this symposium. I describe an approach to springs ecosystem stewardship planning, and review and describe restoration and feed-back monitoring approaches. The MNA Springs Stewardship Institute has developed its secure, relational Springs Online database (SpringsData.org) to provide springs stewards with enhanced ability to archive, analyze, report upon, and share information and assess the status and functionality of aquifers and springs across private property, agency, Tribal, interstate, and international boundaries. Despite improving reception of these issues, there remains limited agreement on the scientific lexicon, best science and management practices, and the urgency of conservation facing these remarkable ecosystems. In reviewing these challenges, I recommend that renewed vigor and attention be directed towards resolution of scientific and management conflicts to help society move towards a sustainable future of springs stewardship across local, state/provincial, national, and global scales.

The Global Demise of Springs Ecosystems: Who's to Blame?

Lawrence E. Stevens
Museum of Northern Arizona Springs Stewardship Institute
Flagstaff, Arizona; Larry@SpringStewardship.org

Springs ecosystems are among the most biologically and culturally diverse, productive, and threatened ecosystems on earth, occurring in abundance in both terrestrial and subaqueous settings. Springs support disproportionately large numbers of rare and endangered species, and springs ecosystem goods and services include high quality water, vegetation, fauna, habitat, mineral deposits, and recreation, other economic, and aesthetic and spiritual resources. However, springs have been broadly neglected or overlooked by modern society, land management agencies, and the scientific community. In this talk I describe five reasons that contribute to this unusually broad neglect of springs. 1) As the language of science, homology in English results in confusion of springs with mechanical devices and seasons. Also related to language, the scientific community has not agreed on a lexicon to describe springs classification, identification of rare types, and assemblage characteristics. 2) Federal policy in the United States and elsewhere excludes consideration of groundwater-dependence among wetland ecosystems, resulting in failure to recognize springs as wetlands, thereby excluding springs from consideration in federal habitat management. 3) Springs are complex, highly individualistic, multi-gradient, linked aquatic and riparian ecosystems that have long been regarded as hydrologic features, and only relatively recently as ecohydrological systems. Such complexity and multi-dimensionality generates the need for interdisciplinary research teams and led, in relation to (2) above, confusion over appropriate funding agencies, further limiting research. 4) Although ecosystem ecology was first thoroughly explored at Silver Springs in Florida, (2) and (3) have led to a lack of scientific interest in springs ecosystem ecology. 5) The legal emphasis on appropriation of "every last drop", and policy-based separation of surface and ground waters (2 above) has engendered a highly polarized public sentiment to ever more jealously guard private water rights and ignore appropriate ecosystem management practices. The result of these interacting factors has been systematic state-based, national, and global neglect and degradation of springs ecosystems, with estimates of levels of ecological impairment exceeding 90 percent in many regions, and undocumented extinctions of springs-dependent species. By describing the reasons for, and extent of this neglect, we hope to renew public, scientific, and governmental awareness and interest in springs ecosystems, whose ecological importance in landscape, water, natural, and cultural resource integrity, function, and management warrants consideration of a global springs ecosystem stewardship initiative.

The Contributions, Possibilities, and Challenges of Citizen Science in Relation to Springs Ecosystems and Field Data Collection

Stephanie Wacha

Spring Stewardship Institute, Flagstaff, AZ

Stewardship is defined as the careful and responsible management of something entrusted to one's care. While years of education and experience go into stewardship at the level that we are talking about at this gathering, a critical piece of the stewardship, caring, is not exclusive to researchers and policy makers. Citizen science allows a committed and concerned public to express their care in scientifically reliable yet simple ways.

In 2017, SSI used a template created for collaborating with the Forest Service to build an app for backcountry users in the Grand Canyon. In the Grand Canyon region, we have a healthy supply of regular backcountry users, including commercial guides, both on foot and along the river corridor. Most guides have a broad base of knowledge applicable to springs inventory and monitoring, as they are able to determine site geomorphology, identify flora and fauna, and estimate flow of a spring ecosystem. The app is for smartphones and tablets, available offline, for users to inventory and monitor springs. The app has been tailored to fit the knowledge of the user base, in order to make it accessible, and to ensure reliable data collection. Rather than doing in-depth surveys requiring time, resources, and expertise, multiple cursory surveys can be collected at more frequent intervals. Though the results of the first year of this app were not as extensive as hoped for, a significant amount of new data was collected. This project raises a number of questions for consideration moving into the future regarding best practices for participant engagement, platforms for engagement, and dataset reliability.

Genetic Population Structure in an Arid Landscape: A Comparative Study of Chihuahuan Desert Invertebrates

Ashley D. Walters[1] and David J. Berg[2]

[1]Department of Biology, Miami University, Oxford, OH 45056

dunithad@miamioh.edu **Presenter**

[2]Department of Biology, Miami University, Hamilton, OH 45011

Organisms with similar geographic distributions often differ in population genetic structure, typically resulting from differences in biological characteristics. We used microsatellite loci to investigate the population genetic structure and genetic variation of four desert spring invertebrates: an undescribed snail species within the pulmonate genus *Physa*, two species of prosobranch snails of the family Hydrobiidae (*Juturnia kosteri* and *Pyrgulopsis roswellensis*), and the amphipod *Gammarus desperatus*. The latter three species are federally listed as endangered. The location of this study, Bitter Lake National Wildlife Refuge, New Mexico, U.S.A., represents the entire range for the hydrobiids and *G. desperatus*, while *Physa* is limited to a larger portion of southeastern New Mexico. We did not find evidence of significant population genetic structure for *Physa* and *G. desperatus*, suggesting that neither species was dispersal-limited. The same was not true for the hydrobiids, which showed differing patterns of population structure throughout the refuge. Despite similarity in morphology and range, population structure suggested relatively limited dispersal ability for *J. kosteri*, and even less for *P. roswellensis*. Dispersal-limitation over small spatial scales (on the order of hundreds-to-thousands of meters) in hydrobiids (so-called "gilled snails"), likely accounts for microendemicity within this group, such that individual spring systems each harbor their own unique species. Not only do our results provide insight into fundamental interactions between species and their landscapes, they also suggest that individual spring systems are likely to harbor an array of endemic, poorly dispersing invertebrates that will require conservation and management efforts.

Citizen Monitoring of Springs Value to Wildlife in Madrean Landscape Linkages and Other Focal Areas

Scott Wilbor[1], Sami Hammer[1], and Meagan Bethel[1].

[1]Sky Island Alliance, 406 S. 4th Avenue, Tucson, AZ 85701,
email: scott@skyislandalliance.org

Sky Island Alliance (SIA), a bi-national Madrean Archipelago conservation organization has focused it conservation work on springs since 2012. Springs are critical water and habitat resource for regional biodiversity and wide-ranging Madrean wildlife. In order to better understand wildlife use of spring water sources and habitat within the Madrean Archipelago and to guide conservation management of these resources by our public land management agencies SIA developed a citizen-science monitoring program beginning in 2014 (SIA's Adopt-A-Spring Program, volunteer-led spring-specific repeat surveys). Beginning in 2016 we evolved our program to integrate citizen-science monitoring of springs and their wildlife values.

With a limited volunteer corps capacity and a desire to fulfill an unmet knowledge need, we have recently focused both our spring and wildlife monitoring on springs within threatened landscape-level wildlife linkages of the region, beginning on the U.S. side of the border, as well as a suite of springs that may show the range of climate-change impacts over time. As a basis for focusing our efforts on linkages, we have use existing regional linkage models. Major threats to linkages include recent proposals for increased border infrastructure and development and human-use near still viable highway crossings. This presentation will outline our new integrated citizen-science projects, based on springs and wildlife linkages. We provide results of wildlife use through cameras and biodiversity value at monitored spring sites. We also provide a set ecosystem condition indicators that consulted managers and researchers believe will be best able to track trends in spring's site conditions of these exceptional landscape resources.

Notes