Beaver Creek Experimental Watershed
Proposed NEON Domain 13 Core Wildland Site

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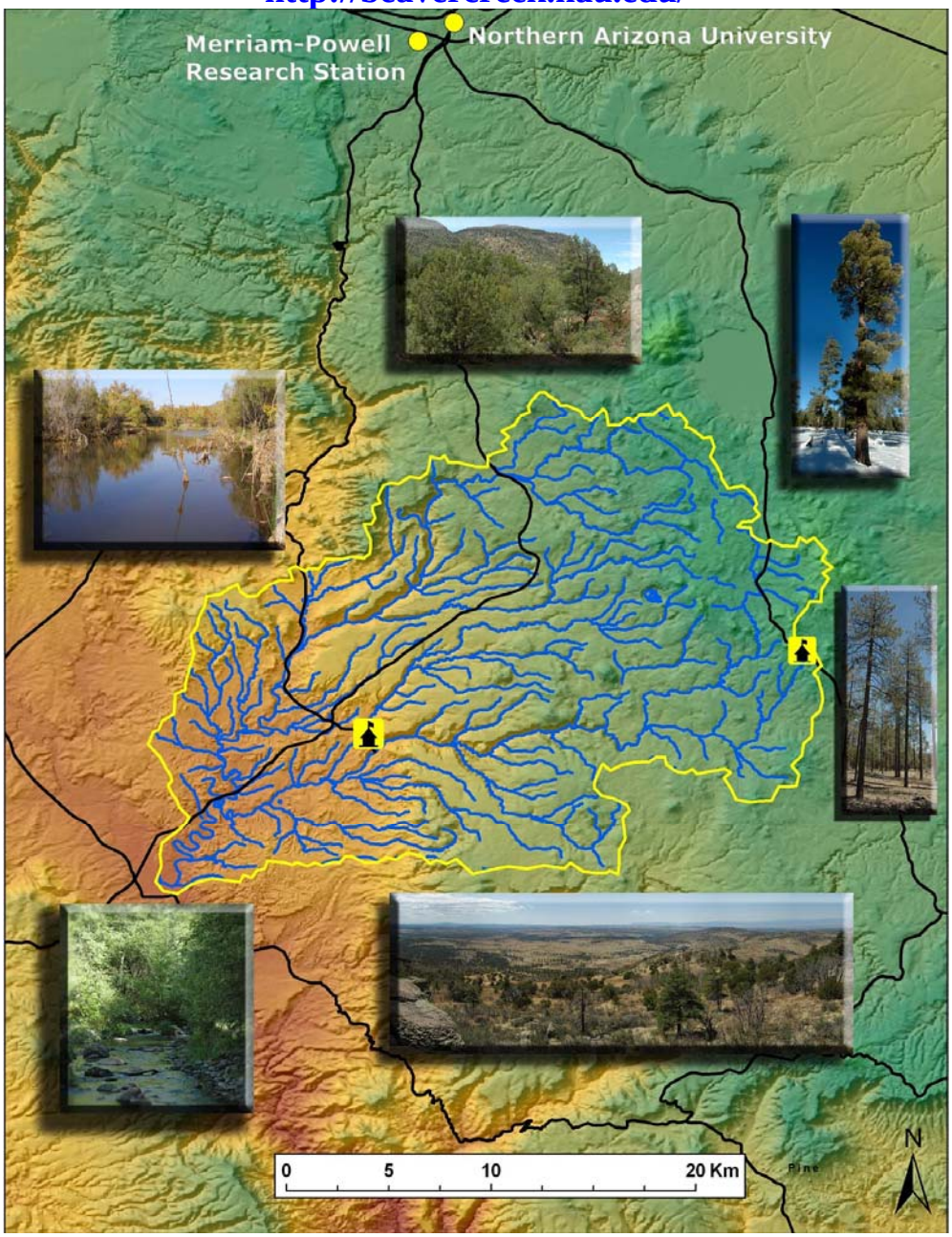
http://beavercreek.nau.edu/



I. SUMMARY - The Beaver Creek Watershed is located in the southwest portion of Domain 13 (Lat 34.755N Long 111.485W, 114,121 ha) and is an exemplary core site for five key reasons: **1)** Ecologically representative of Domain 13; **2)** Ideal for supporting both terrestrial and aquatic research to address the two focal NEON drivers, climate change and land use; **3)** Available regional expertise, laboratories, and complementary research to ensure leveraging of NEON funds; **4)** Institutional support and availability of facilities; and **5)** Strong legacy of research that NEON can build upon. Thus, the Beaver Creek Watershed has many of the critical elements for a core site to be successful, and together with other core sites, would realize the national-scale observatory network for monitoring ecological dynamics. **Ecological Representation -** The Beaver Creek Watershed is dominated by four broad vegetation types: Ponderosa pine montane forest, pinyon-juniper woodlands, desert shrubland, and grasslands. Together these vegetation types comprise 99% of the Beaver Creek Watershed and 90% of Domain 13 vegetation types, making the area highly representative of Domain 13 vegetation. The proposed site for the Advanced BioMesoNet Tower is in the Ponderosa pine montane forest, which is a widespread habitat in the western US and important from both ecological and human perspectives. A wide range of aquatic habitats occur within the watershed, including gauged streams, springs, and a lake. **NEON Drivers: Climate Change & Land Use -** Climate change and land use strongly impact Domain 13 ecosystems. Paleontological studies and recent experimental research demonstrate that the many species in Domain 13 are strongly sensitive to climate change, including ponderosa and pinyon pines, the dominant tree species of forests and woodlands in the Domain. These trees, which are regionally important for hydrological recharge, biodiversity, and carbon sequestration, exhibited severe mortality during recent years of high temperature and precipitation anomalies. Experimental work shows >50% species loss and replacement in response to warming in the herbaceous communities of the desert grassland, ponderosa, and pinyon biomes. Shifts in community composition and performance of keystone species over elevation gradients and ecotones are important barometers of climate change, and the 1625 m elevation change along the watershed provides an excellent gradient of habitat types and ecotones in which to assess climate change impacts. Domain 13 is characterized by federal, Native American, and state lands that focus on timber, grazing, fuel reduction, homes, and recreation, all land uses that occur within the Beaver Creek Watershed. Also close to urbanizing Flagstaff, Beaver Creek is an excellent area to document the impacts of land use change. **Expertise and Research -** Nearby Northern Arizona University and partner institutions can provide expertise needed to support NEON activities. There are 23 laboratories and research groups that include over 75 PhD researchers in the fields of ecology, genetics, hydrology, soils, GIS/Remote Sensing, climatology, and informatics that can provide expertise for the core site. A number of institutions and individual researchers have ongoing studies in the watershed, continuing the rich history of research. **Institutional and Facilities Support -** The Coconino National Forest, USDA Rocky Mountain Research Station, and Northern Arizona University are committed to a thirty plus year future for this core site. Two USFS ranger stations, the Merriam-Powell Research Station, and Northern Arizona University can provide housing, facilities, field support, research laboratories, cyberinfrastructure, and outreach. **Research Legacy -** Beaver Creek is a UNESCO Man and the Biosphere Reserve and a designated US Forest Service Experimental Watershed, which was established to function as a major center for watershed management research. The Beaver Creek Watershed has extensive “legacy data” available on the area’s climate, hydrology, fire, land use and management. This research has produced over 200 publications and reports on ecology, silviculture, geology, soils, and paleoecology. Additional documentation can be found at **http://beavercreek.nau.edu/** .

II. Beaver Creek Watershed (BCW): Domain 13 Characteristics

Section II.1 Ecology-Hydrology-Climate - Domain 13 is large, encompassing both the Colorado Plateau and Southern Rocky Mountain bioregions, and it is diverse, with 111 distinct vegetation associations found within the domain (USGS SW ReGAP, 2004-2005). The Beaver Creek Watershed (BCW), which is located 80 km south of Flagstaff Arizona, has numerous characteristics that exemplify those of Domain 13. We focus on how the biota, climate, hydrology, soils, and land use of Beaver Creek are characteristic of the domain.

Biota: The 1625 m elevation gradient within the watershed supports a variety of vegetation types, including ponderosa pine montane forest, pinyon-juniper woodlands, desert shrubland, chaparral and grasslands. Together, these comprise 99% of the BCW and 90% of Domain 13 vegetation types, making the BCW highly representative of Domain 13 vegetation (**Figure 1**). BioMesoNet Towers are targeted for the upper watershed in ponderosa pine forest. Ponderosa pine is the most widely distributed pine in the western US and in Domain 13 and is regionally important for hydrological recharge (Baker 1986, Ffolliott et al. 1989), biodiversity, and carbon sequestration. The Ecological Restoration Institute (NAU) is focused on understanding the ecology of the important forest ecosystems in the Interior West. Understanding the restoration ecology of natural biodiversity, forest structure, surface fire and other disturbance regimes is critically important in forests and woodlands, which have been subject to catastrophic regional fires (e.g., Rodeo-Chedeski, Los Alamos). In addition to the documented impacts of overgrazing, over-harvesting, and fire exclusion, these forests and woodlands also appear to be exhibiting effects of climate change, as warm conditions have fostered drought and unprecedented bark beetle outbreaks, in addition to severe wildfires in western forests and woodlands (Breshears et al. 2005).

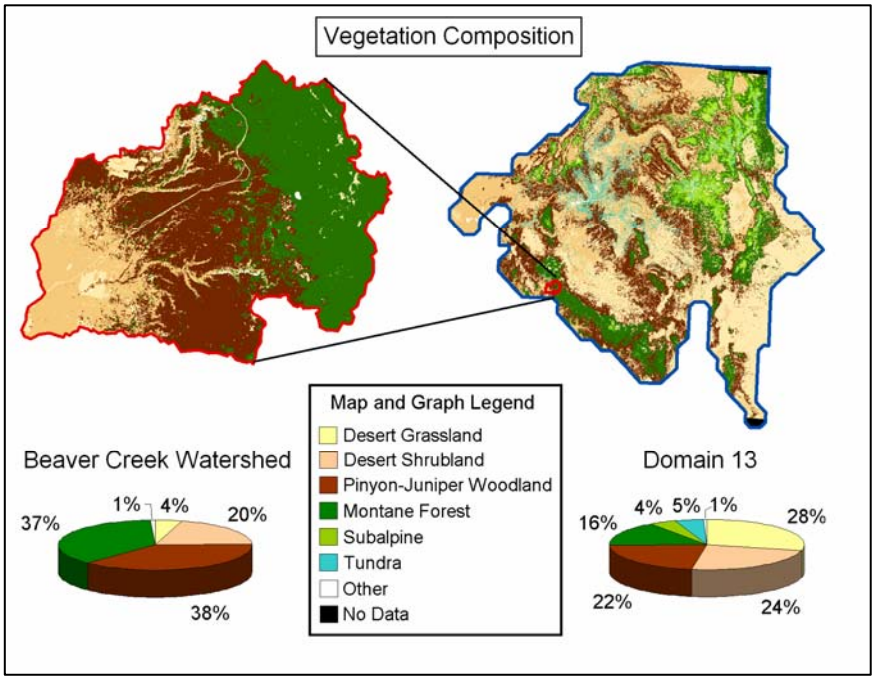


Figure 1. Beaver Creek is representative of the major vegetation types in Domain13.

Vertebrate and plant diversity in the BCW is high, and reflects the total biological diversity the watershed supports, including invasive species (**Table 1**).

Table 1. Vertebrate and plant diversity in the Beaver Creek Watershed (based on USGS SW ReGAP)

	Birds	Amphibians	Mammals	Reptiles	Fish	Decapods	Plants
# of Species	114	12	54	42	15	2	186
# of Invasives	3	1	0	0	7	2	45

Climate: The climate of the Beaver Creek Watershed mirrors the climate of Domain 13, based on an analysis of 800m PRISM data. Climate data summarized in **Table 2** shows that the mean climate and elevation values for the Beaver Creek Watershed are remarkably close to those of Domain 13. The seasonality of precipitation in the Intermountain West is thought to be equally important as total precipitation. The proportion of annual average precipitation received during the monsoon season (from high to low elevation sites in the watershed) brackets that of Domain 13, underscoring how well it is able to represent Domain 13 in terms of seasonal moisture receipt.

Table 2. Climate and elevation characteristics for Domain 13 and the Beaver Creek Watershed (PRISM Group, 2004). Note: the proposed BioMesoNet Tower sites are located in the high elevation portion of the watershed.

PRISM Climate Data (1971-2000)	**Domain 13**			**Beaver Creek Watershed**	
	All Elevations			High Elevation	Low Elevation
Climate and Elevation	**Mean**	**Lower 95% CI**	**Upper 95% CI**	**Mean**	**Mean**
Elevation (m)	2060	1023	3097	2099	970
Annual Average Temp. (Celsius)	9.0	1.2	16.9	8.4	16.3
Annual Average Precip. (cm)	41.5	4.7	78.4	67.2	36.8
Annual Average Monsoon Precip. (cm)	13.8	2.5	25.2	18.8	13.8
% Monsoon Represents of Annual Precip.	33.3%			28.0%	37.5%

Hydrology: Beaver Creek is an outstanding area for conducting aquatic studies in Domain 13 because it has the representative hydrology, water issues, and has been designated as an experimental watershed and UNESCO Man and the Biosphere designation to specifically address water-related issues. It typifies southwestern U.S. hydrological system, with both perennial and intermittent reaches, drought-flood cycles, and hydraulically connected surface and groundwater**.** Beaver Creek is a major drainage into the Verde River, which then flows into the Salt River, providing water to the expanding Phoenix metropolitan region, the fastest growing urban area in the USA. The growing communities of Sedona, Oak Creek, Lake Montezuma, Rimrock, and Camp Verde all place significant demands on available water. Exotic fishes and crayfish provide a challenge to restoration of the perennial Wet Beaver Creek, while beavers are actively restoring pond habitats in Dry Beaver Creek. There are currently ten active stream gauges distributed in the upper portion of the watershed. Stoneman Lake, a natural, permanent lake in the Arizona, is also located in the upper portion of the watershed. Paleoecological work in Stoneman Lake has documented 9,000 years of vegetation change in the watershed (Hasbargen 1994).

Soils: The Beaver Creek Watershed contains three among the six most abundant soil orders present in Domain 13, including: Alfisols, Inceptisols, and Mollisols. According to the U.S. General Soils Map, the Beaver Creek Watershed contains eight different soil types. Although the watershed's area represents only 0.2% of Domain 13, these same eight soil types cover 2.1% of Domain 13's aerial extent (NRCS Soils Webpage).

Section II.2 Ecological Drivers - Domain 13 is greatly influenced by gradients of human population density; it is one of the fastest growing regions in the country. Population centers are located primarily along the domain boundary (**Figure 2**). Thus, our proposed core site is strategically located to capture both dispersed impacts (e.g. recreation, second homes), and human developments that are increasing dramatically.

The interior of Domain 13 is dominated by Federal & Native American lands (**Figure 2)**. Each land management agency and tribal government have different priorities of land use and management, although within any one ownership land use designation varies from protected wilderness to heavy recreation, resource extraction, and commerce. The Beaver Creek Watershed

reflects the domain in that it is predominantly managed by federal agencies (USFS and the NPS). There is a full spectrum of stand structures within the ponderosa and pinyon-juniper vegetation types in the watershed, which would be available to expand studies to compare ecological consequences of different stand structures. For example, vegetative manipulations consisting of different levels and patterns of tree thinning and control of herbaceous vegetation were applied between 1957 and 1983 in a paired design to 24 sub-watersheds of the larger BCW (Baker and Ffolliot 1998). These manipulations, designed to affect and test site water balance, have created a mosaic of current stand structures available for future research.

The BCW is an ideal location to monitor the ecological impacts of climate change because of its pronounced elevation gradient and its geographic location within the region. Elevation gradients, such as the one found in the BCW, are sensitive sentinels for detecting the differential effects climate change. In addition, the BCW is located near the northern extent of monsoonal precipitation, and thus, in combination with other sites inside and outside of Domain 13, would contribute to NEON's ability to detect climate change impacts.

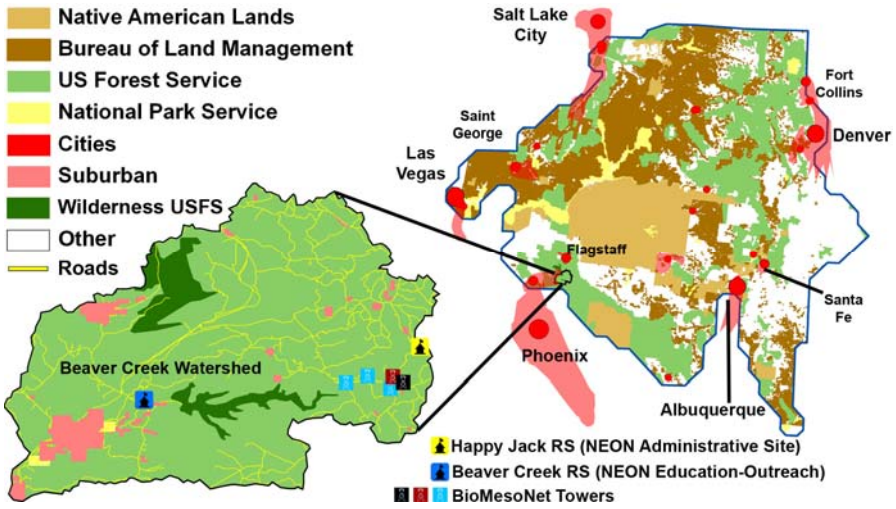


Figure 2. Approximately 83% of Domain 13 is owned by three federal land management agencies and Native American Nations. Centers of human populations are found on the boundaries of the domain. The Beaver Creek inset shows that 91% of the watershed is managed by the USFS and NPS. Recreational pressures occur throughout and human developments are growing rapidly in the southern portion of the watershed.

III. Ownership and Accessibility

Section III.1 & 2 Ownership - The proposed Beaver Creek Domain 13 core site is owned by the United States Forest Service (USFS) as part of the Coconino National Forest (**Figure 3**). The watershed is surrounded by large areas also owned by the USFS. The access roads to the site are maintained by the USFS. The Coconino National Forest covers 737,133 ha. in Northern Arizona and has a staff of 151 people with headquarters in Flagstaff. The Mormon Lake Ranger District, which oversees the proposed site, has Ranger Stations in Flagstaff and Happy Jack. We are proposing the Happy Jack Ranger Station to be the NEON Administrative site (**Figure 4**).

Section III. 3 & 4 Use, Access, and Easements - We propose locating the Advanced BioMesoNet Tower System in an unmanaged ponderosa pine stand, in the upper part of the watershed. An experimental BioMesoNet Tower could be located within 1 km of the advanced tower. The three additional basic BioMesoNet Tower Systems will be located down the elevation gradient from the ponderosa pine forest, through the pine-oak forest, and will terminate at the ecotone with the pinyon-juniper woodland. This placement of instrument towers will allow

documentation of changes in climate factors over the entire range of dominant forest vegetation in the BCW, and will include key ecotones where effects of changing climate can be compared among co-occurring species (Adams & Kolb 2004, 2005).

Restrictions on use would be those imposed by the USFS and the National Environmental Protection Act (NEPA) process. Because NEON core site use is compatible with the USFS planning for the watershed and because we have avoided areas of particular environmental or cultural concerns (**Figure 4**), there should not be any onerous restrictions on research use. There are five grazing allotments within the watershed; one of the larger allotments is provided to the V-V Ranch (**Figure 3**), which is owned and operated by the University of Arizona. The grazing allotment for the proposed Advanced BioMesoNet Tower site is held by the Bar D Cattle Company. The Coconino National Forest has consistently allowed fenced exclosures for the purpose of research within lands under grazing leases. The Advanced BioMesoNet site is 69 highway kilometers plus 3.3 km of dirt road from Flagstaff, AZ. Flagstaff has a commercial airport. The site is near a power transmission line easement (**Figure 4**). There are several potential sites near the site marked on the maps that also meet NEON core site criteria. The various sites have tradeoffs of distance to power transmission lines, number of miles of dirt road access, and degree of waterway access. All potential sites have large enough areas with less than five degrees slope for the location of a flux tower.

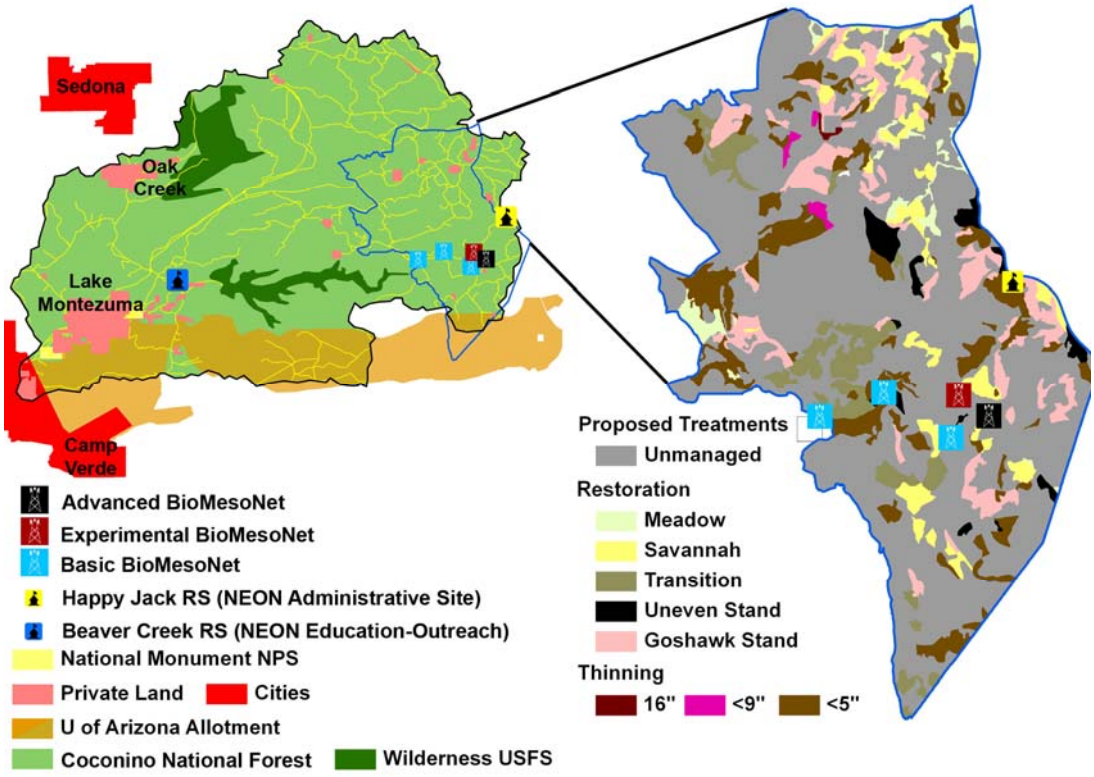


Figure 3. Beaver Creek Watershed (Left) highlighting land ownership and key NEON locations. The Uof A owns the V-V ranch in the lower part of the watershed. The expanded portion depicted on the right shows the location of the BioMesoNet Towers and proposed USFS restoration and thinning treatments.

Section III.5 30-Year Availability - The Coconino National Forest's strong support for the response to the NEON RFI indicates its willingness to come to an agreement which will ensure 30 years of access through their permitting/leasing processes. The Forest Service will maintain

the roads that provide access to these sites. They actively support the use of Happy Jack RS for an administrative site, which we expect to share with the Lowell Observatory, who is using it for an administrative site for their nearby $30 million telescope sponsored by the Discovery Network. We have also been working with the Coconino NF to develop the historic buildings at the Beaver Creek RS into an education center.

Section III.6 Experimental Feasibility - Because the BCW is a USFS Experimental Watershed and designated as a UNESCO Man and the Biosphere Reserve, there is a very good match between the desired use of the area and NEON requirements. Hence, NEON infrastructure and experiments are compatible with land use planning for the area. The land area available is comprised of diverse habitats and landforms that would be able to accommodate the addition of many experiments. Power is available and heavy equipment will have access to areas for building experimental infrastructure and monitoring networks. Water addition experiments would be possible, either by building a water line from the administrative site, establishing a well at the site, or by trucking water to the site. Support facilities, staff, vehicles and other equipment required to access field sites year-round, could be located at the Happy Jack Ranger Station, which is10 km from the Advanced BioMesoNet Tower.

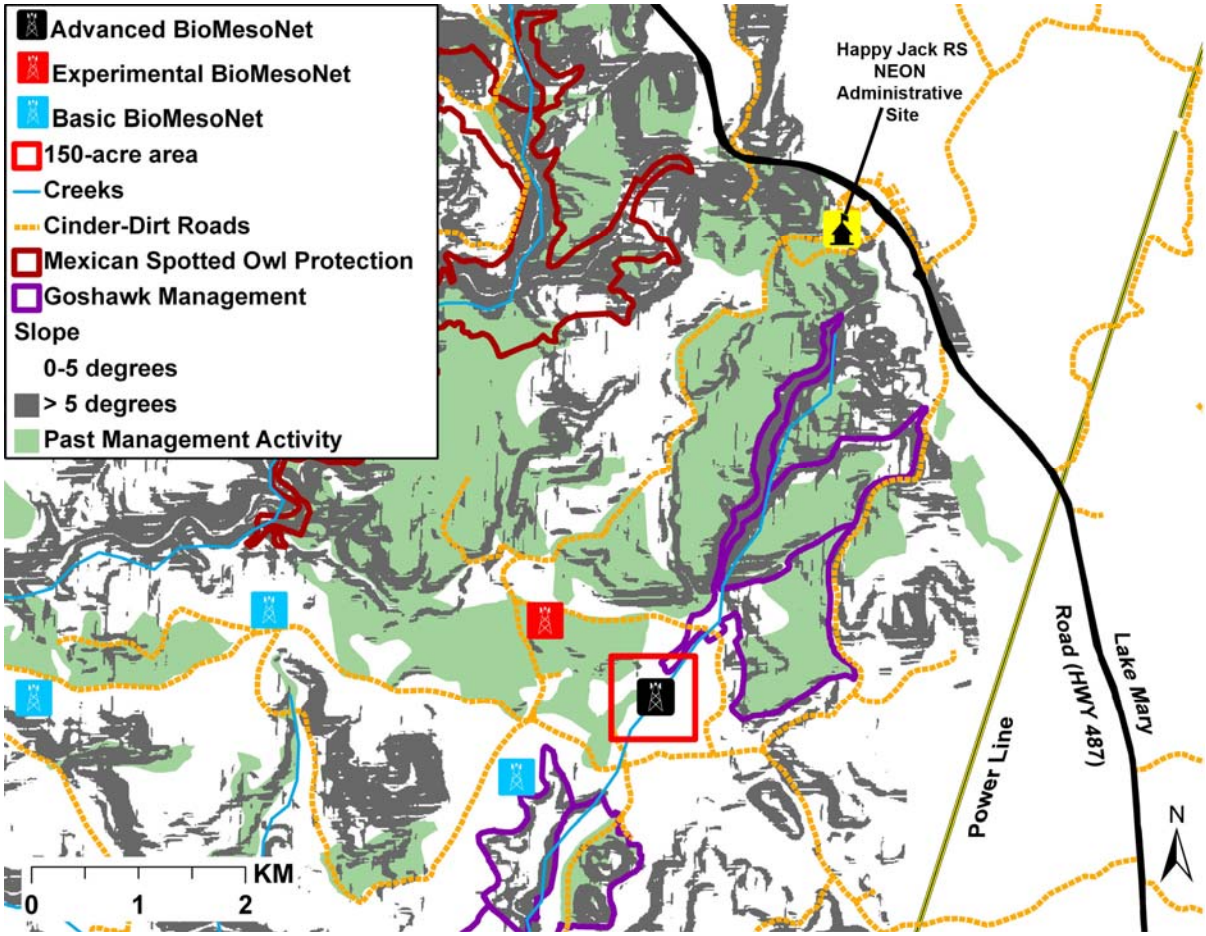


Figure 4. Proposed sites for the five BioMesoNet Towers and the NEON Administrative Site (Happy Jack RS). In selecting sites we have accounted for distance from administrative site, paved roads, power lines, past management, proposed management (see Figure 3), vegetation, creeks, and slope (for Flux towers).

Section III.7 & 8 Environmental Assessment and Sensitivity - The types of infrastructure and activities anticipated for NEON deployment (flux towers, research staff access, experiments) are

being incorporated into an ongoing NEPA Environmental Assessment for the USFS Beaver Creek Watershed Management Plan. We have used information from this planning process to avoid threatened and endangered species habitat areas and to avoid intensive management and timber resource use areas (**Figures 3 & 4**). Because anticipated NEON infrastructure needs are being considered in the current NEPA Environmental Assessment, NEPA compliance for deployment should not be problematic. We have avoided areas of Mexican spotted owl habitat (threatened species) by large margins in our selection of a suitable location for the proposed core site. Treatment areas for promoting improved goshawk habitat (species of concern, not threatened or endangered) are nearby, but are not included in the proposed core site or experimental set-aside. There are no known archeological concerns on the site. The power line extension would follow an existing road to reduce environmental/archeological impacts. The one significant, and only known, wetland on the site is the seasonal creek traversing the site. The site access road does not cross this creek; hence it will be easy to avoid any disturbance to wetlands during infrastructure construction. The main visual concern is anticipated to be with lighting. Hence, exterior, night-time lighting will be minimized and shielded in accordance with "dark-skies" recommendations.

A NEPA Environmental Assessment was also recently completed by the USFS with the Lowell Observatory for the Happy Jack Ranger Station and the Discovery Channel Telescope construction on a nearby hill. This Ranger Station is the proposed NEON Administrative Site and thus it is worth noting that no environmental or historical issues were found to prevent the development of scientific and related support infrastructure at these sites.

Section III.9 Remote Sensing Considerations - There are no homeland security or airspace restrictions of concern in the area. Paved roads located to the east of the site would provide permanent targets for remote sensing activities (**Figure 4**-Lake Mary Road/Hwy 487).

IV. Infrastructure

The existing support facilities and sites for further development of support facilities include: The Happy Jack Ranger Station (USFS), Beaver Creek Ranger Station (USFS), Merriam-Powell Research Station (Northern Arizona University and The Arboretum at Flagstaff), and the NAU campus. Substantial savings in the costs associated with supporting the research site can be gained by use of the USFS Happy Jack Ranger Station. The ranger station is within 10-15 km of proposed wildland sites and provides an ideal location for a NEON administrative site.

Section IV.1 Housing - The Coconino National Forest would welcome NEON as an additional partner (via permit or lease) at the Happy Jack Ranger Station (**Figure 5**). The Forest Service has already welcomed the Lowell Observatory to the site for use as a base of operations for the Discovery Channel Telescope, which is within 2 km of the Station. The USFS would willingly provide a site to build housing at the Happy Jack Ranger Station at a low cost. There is space for at least two housing structures with 2000 sq ft footprints. Also currently available at this site, are parking places and hook-ups for mobile housing units. NAU's Merriam-Powell Research Station has just completed construction of year-round, visiting researcher/student housing for up to 26 people at one time. This housing

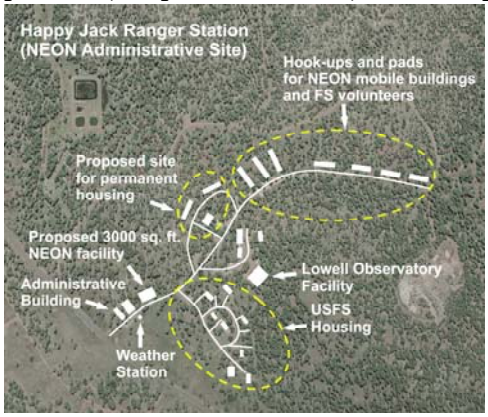


Figure 5. Happy Jack Ranger Station and proposed NEON Administrative Site.

would be available to users of the NEON core site. The Merriam-Powell Research Station is located south of Flagstaff on property owned by the Arboretum at Flagstaff and is 72km from the BCW administrative site.

Section IV.2 Laboratory Capabilities – Laboratory and research space resources available or potentially available at the Happy Jack Ranger Station include: sites and hook-ups for mobile units, space for a 3,000 sq ft laboratory facility near the existing office building, and an office building that the USFS plans to vacate within the next 5-10 years (**Figure 5**). Discussions with the Forest Service indicate that a thirty year commitment will be easily obtainable for use of these resources. The site has excellent driving access and is approximately a one-hour drive from Flagstaff. Since the Happy Jack Ranger Station was planned to support 100 people, full-time, the development associated with NEON would fit well with planned use and capacity for the site. There are no known biological or archeological resources of concern. Buildings that would be removed to make space for new housing are already planned for demolition by the USFS.

Laboratory space is available at the Merriam-Powell Research Station in conjunction with The Arboretum at Flagstaff. On the campus of Northern Arizona University many higher-end laboratory capabilities are available to meet needs that might not be available closer to the site. Facilities include the Environmental Genomics and Genetics Laboratory, Colorado Plateau Stable Isotope Laboratory, Chemical Analysis Lab, Imaging and Histology Core Facility, Greenhouses, Natural History Collections, GIS Laboratory, superb video-conferencing and interactive distance learning capabilities, conference facilities, and an excellent library (Also see **Table 2**).

Section IV.3 Power and Water - Electricity would be available to the field site from a major north-south power transmission line that passes within approximately 3 km of the BioMesoNets. The same power line supplies the Happy Jack Ranger Station (i.e., NEON Administrative Site). Water for the wildland core site could be trucked from Happy Jack RS or come from a new well. Gas would be supplied by propane tanks. The USFS would provide NEON access to the infrastructure improvements at Happy Jack Ranger Station in return for assistance with systems maintenance and upkeep. The utility, driveway, and parking infrastructure at Happy Jack are designed for 100 full-time resident-staff and are currently under-utilized. There are telephone and electric lines to structures on the Happy Jack Ranger Station site. Water is supplied from two 10-15 gallon/minute wells with a 30k gallon storage tank on a hill, and the septic system is certified for a 100 person capacity. Gas is supplied via propane tanks.

Section IV.4 Cyberinfrastucture – Internet to the Happy Jack Ranger Station is currently available via T1 service provided by Qwest and the local phone company. Data connectivity from Happy Jack to the field site will likely utilize directional radio. Repeater towers may be necessary to get directional radio to the instrument towers.

Northern Arizona University currently has both 200 Mbits/sec and 1000Mbits/sec connections to the wider Internet. Standard Internet connectivity is provided through two redundant 200 Mbits/sec Internet connections. NAU has an Internet 2 connection of 1000 Mbits/sec available for use by data intensive projects such as a NEON core site. This connection is currently underutilized and would be available for NEON connectivity. Currently the yearly average utilization is approximately 9% in and 2.5% out of full capacity (peak 15%).

Data storage and management will utilize standard practices as developed by the Organization of Biological Field Stations (OBFS), Long Term Ecological Research Network (LTER), the Knowledge Network for Biocomplexity (KNB), Ecoinformatics.org and the National Center for Ecological Analysis and Synthesis (NCEAS). Data will be stored on centralized redundant

servers housed in the NAU Information Technology Services (ITS) server facility. The ITS server facility provides 24-hour security, redundant UPS power and fire protection. Data will be backed up to the ITS automated tape library via the campus Intranet backbone on a regular schedule to be determined according to the rate of dataset change. The ITS tape library is housed in a different building from the server facility, providing the benefits of automated off-site back up for datasets. Datasets will be stored using standards-based and open source (where possible) methods in order to ensure long-term access to datasets. Datasets created in proprietary formats will be converted to non-proprietary formats for long-term storage and assured access. All datasets will be documented using standards-based metadata. A data librarian or manager will ensure that data documentation policies are followed by all users.

Metadata for all datasets will use the Federal Geographic Data Committee: Content Standard for Digital Geospatial Metadata (FGDC CSDGM) standard for all applicable datasets. We will convert to the ISO 19115 standard as soon as it is implemented. This conversion process (cross-walk) has already been developed by FGDC partner organizations. NAU can train users in proper data documentation and management; we already do this for tribal governments under a grant from FGDC. EML and/or Dublin Core metadata will be used for datasets which can not be properly documented using the FGDC standards.

Section IV.5 Roads - The Advanced BioMesoNet site is 69 km of highway from Flagstaff, AZ. miles plus 3.3 km of dirt road. The other BioMesoNet sites are within 6 km of the Advanced BioMesoNet site via dirt roads.

Section IV.6 Security – US Forest Service personnel currently provide security to the proposed core wildland research site, and additional measures, such as fencing and locks, will be implemented. The Merriam-Powell Research Station is behind locked gates (off business hours), and campus resources are secured as is typical for a university campus.

Section IV.7 Expertise -Northern Arizona University has great depth of human expertise in the environmental science field and strong relationships with agency offices and the community. NAU has nationally respected departments /schools in Forestry, Biology, Engineering and Environmental Sciences (see http://www.mpcer.nau.edu/EnvironmentalCourses/). Laura Huenneke, the lead scientist for this proposal, is the Dean of the College of Engineering and Natural Science and co-Chair of the NEON education committee. Several centers at NAU and local partner institutions can contribute to a broad base of support for the NEON domain core site (**Table 3**). The Merriam-Powell Center for Environmental Research has coordinated NAU's participation in NEON discussions for the past six years. NAU has expertise in population, community, and ecosystem ecology, molecular genetic analyses, stable isotope analyses, forest ecophysiology, aquatic ecology, remote sensing, GIS, as well as database design/management, environmental engineering and wireless sensor development/deployment (LeRoy et al., 2006; Simonin, et al., 2006; Whitham et al., 2006; Hungate et al., 2003; Brown et al., 2001). Biological and paleo-ecological collections are also available. Many faculty and agency researchers already conduct research in the Beaver Creek watershed and use the site to support undergraduate and graduate education. The Ecological Restoration Institute is a national leader in restoration applications and fire ecology, and is interested in initiating experimental restoration treatments and incorporating landscape analysis and planning tools (Forest Ecosystem Restoration Analysis).

Table 3. Expertise available for NEON activities in NAU and local partner institutions.

Facility/Research Group	Expertise	Contact(s)
Ecological Restoration Institute	Ecology & Restoration of Ponderosa Pine Ecosystems	W. Covington, P. Fulé, D. Huffman
Flux Tower Study Group	Operate 3 Eddy Flux Towers in Ponderosa pine habitats	T, Kolb, S. Hart, G. Koch, B. Hungate
Pinyon Ecology Research Group	Ecology (Population, Ecosystem, Community, Evolution)	K. Gehring, T. Whitham, G. Koch
Soil Ecology Group	Ecology (Ponderosa, Pinyon-Juniper, Grassland)	S. Hart, D. Anderson, N. Johnson, K. Gehring
Aquatic Ecology Group	Algae, Diatoms, Invertebrates, Fishes, and Water Quality	J. Marks, M. Watwood, J. Shannon
Cottonwood Evolutionary Ecology Group	Riparian ecology, genetics, restoration	T. Whitham
Colorado Plateau Stable Isotope Lab	Full Spectrum Ecological Isotope Analyses	R. Doucett, B. Hungate, R. Foust
Environmental Genetics & Genomics Lab (ENGGEN)	Complete Genetic Analyses	P. Keim, G Allen, T. Whitham, K. Gehring
Geospatial Research and Information Lab (GRAIL)	GIS & Remote Sensing	P. Heinrich
WiSardNet	Wireless Sensor Technology Development & Deployment	P. Flikkema
ForestERA	GIS & Remote Sensing, Focused on Ponderosa Pine	T. Sisk
Colorado Plateau Biodiversity Center	Natural History Collections, Conservation Genetics, Informatics	S. Sommer
Merriam-Powell Research Station	Environmental Research Support (Logistics, Planning, Coordination)	A. Whipple
Merriam-Powell Center for Environmental Research	Integrate Environmental Research, Education & Outreach	N. Cobb, A. Whipple, T. Whitham
Center for Climate Change	DOE funded climate change research	B. Hungate, G. Koch
Institute for Tribal Environmental Professionals	Native American Environmental Research-Education	M. Khatabi
Center for Sustainable Environments	Human Ecology	G. Nabhan
DIRENet	Ecology of drought impacts on SW Forests and woodlands	N Cobb, E. Doerry
	NAU FLAGSTAFF PARTNER INSTITUIONS	
The Arboretum at Flagstaff	Botany, Education Outreach	K. Haskins
Rocky Mountain Research Station (USFS)	Ecology, Hydrology, Wildlife	C. Edminster
National Park Service Inventory & Monitoring SCPN	Vascular Plant, Aquatic, and Vertebrate Monitoring	L. Thomas
Flagstaff Field Center (USGS)	Remote Sensing Hydrology, Climatology, Geology	B. Reed
Southwest Biological Science Center (USGS)	Ecology, Paleoecology	M. Sogge, K. Cole
Museum of Northern Arizona	Education Outreach	R. Breunig

V. Supplementary Information

Section V.1 Existing Gradients – Elevation gradients and community ecotones are recognized as sensitive sentinels of climate change (Adams & Kolb 2004, 2005). At BCW, researchers can compare community response to climate change, conduct transplants, and measure effects of forest treatments over an elevation gradient. Previous vegetation treatments in sub-watersheds (Baker and Ffolliot 1998) have created conditions ranging from grass, shrub, and tree stands established after experimental clear-cuts to old untreated stands -- providing gradients in biomass, leaf area, and species composition. Finally, there are gradients in land use, from recreational use in the upper watershed to more intense impacts of growing communities in lower elevation areas.

Section V.2 Site History - In 1956, Beaver Creek Watershed was established as a US Forest Service Experimental Watershed; in 1976 it was designated a UNESCO Man and the Biosphere Reserve, to function as a center for watershed management research. The USDA Forest Service Rocky Mountain Research Station is one of several agencies and organizations involved in managing Beaver Creek. As a result, the Watershed has extensive "legacy data" on climate, hydrology, fire, land use and management, with 200-plus publications/reports on ecology, wildlife, silviculture, geology, and soils.

Section V.3 Complementary Research – All entities listed in **Table 3** conduct research directly or indirectly relevant to Beaver Creek, the region, and/or NEON. An example is ongoing research by T. Kolb and colleagues (NAU) on the impacts of fire and forest management on carbon and water fluxes and energy balance in ponderosa pine forests. Research infrastructure, including eddy flux towers, is in place at three locations near the BCW (at the NAU Centennial Forest and Coconino NF). The proposed core wildland site at Beaver Creek would enhance NEON's role in expanding the present Ameriflux network of tower sites in order to improve representation of "southern, southwestern, and Pacific Northwest environments" (Hargrove et al. 2003).

Section V.4 NEON Partnerships - This proposed site draws upon a strong three-way core partnership of NAU and two entities of the USDA Forest Service: the Coconino National Forest and the Rocky Mountain Research Station. Together NEON, RMRS, and NAU bring a critical mass of researchers to bear on a single scientific platform. The Coconino NF has demonstrated interest in the educational aspects of NEON as well as the science. USFS maintains a Beaver Creek Ranger Station facility with high visitor access; the area is targeted for the National Forest's Sinagua Circle educational project, highlighting indigenous cultures and their use of water.

The three Arizona universities have just collaborated to obtain $200,000 from the state-funded Science Foundation Arizona to coordinate NEON activities (funding ARENA, the Arizona Environmental Array). Key non-profit entities for collaboration include Lowell Observatory, The Arboretum at Flagstaff, and The Museum of Northern Arizona. Additional agency involvement includes the USGS, NPS, USFWS, and Arizona Game and Fish. The Beaver Creek Watershed is partnered with La Michilía Biosphere Reserve in Durango, the only temperate forest reserve in Mexico; NAU collaborates with La Michilía through the Instituto de Ecología. We have an excellent working relationship with other institutions and personnel associated with Domain 13 and the national connectivity effort, and we are committed to a coordinating role for all of Domain 13.

Section V.5 Tribal Partnerships - NAU has strong connections with tribal colleges in Arizona and New Mexico (Dine College, Crownpoint Institute of Technology, and Southwestern Indian Polytechnic Institute). We assisted Dine College's effort to put forward two Navajo Nation sites as possible gradient-experimental NEON sites. Other efforts include: 1) REU and Bridges programs serving Native students; 2) Dine College collaboration to improve science courses and transfer to NAU for Dine College students; 3) Field station and field research partnerships on the Prescott National Forest and Canyon de Chelly National Monument; 4) GIS metadata Training for tribal professionals; 5) Several NAU Centers and Institutes for outreach to Native communities (see below).

Section V.6 Education-Outreach - Beaver Creek Watershed offers many attractive characteristics for NEON education and outreach. The location, in easy reach of Phoenix (the nation's fifth largest city, and one of the most rapidly growing) yet also near rural and tribal populations, makes the site appealing to a rare combination of audiences. The strong fit with major drivers of environmental change to be studied (climate and land use) provides a wealth of regionally relevant data and forecasting efforts with local appeal for education. Conversely, educational researchers could examine the effect of diverse cultural and community contexts on audience reaction to NEON programs.

Northern Arizona University has long highlighted environmental science, engineering, and management in its programs. NAU hosts a recently-established IGERT program "From Genes to Ecosystems," and a graduate field ecology course, that results in many published projects, has use the BCW for more than 30 projects. A new program in environmental studies complements existing curricula in environmental science, environmental engineering, and NAU's undergraduate engineering programs have been ranked in the top 40 nationally for three years straight by ***US News & World Report***, in part due to strong emphasis on hands-on design experience that might easily incorporate NEON-related engineering problems.

NAU has long delivered education options across rural Arizona and has developed excellent capabilities for distance learning, with the potential to deliver courses (short, long, non-traditional audiences, different formats) based on NEON educational opportunities and themes. Finally, existing and developing infrastructure in the watershed is well suited to hosting the educational and outreach activities foreseen for NEON. As described above, this infrastructure includes USFS ranger stations and commitment to outreach and education, and the nearby Discovery Telescope (a partnership of Lowell Observatory and the Discovery Network). Curricula for outreach programs at the Beaver Creek Ranger Station, with easy access to Pheonix, are already being developed. The Merriam Powell Center's established commitment to high quality outreach is exemplified by this year's release of "A River Reborn," a PBS documentary highlighting NAU's stream restoration science.

Section V.7 Potential for reaching under-represented populations. Arizona's population of potential students of college age is growing rapidly, especially among Hispanics (both US-born and immigrant). NAU has a special commitment to serve Native American students, who comprise 6 % of total university enrollment. A strong commitment to minority undergraduate engagement is demonstrated by current funded programs such as NIH MSD, MARC, and Bridges programs; Undergraduate Mentoring in Environmental Biology; REU Site programs in multiple fields; and the engineering design sequence. NAU's commitment to Native American communities extends beyond the classroom thanks to efforts such as the EPA-funded training programs of the Institute for Tribal Environmental Professionals. These programs could

disseminate NEON findings and opportunities effectively throughout the tribal nations of the southwest.

LITERATURE CITED

Adams, HD and Kolb TE. 2004. Drought response of conifers in ecotone forests of northern Arizona: tree ring growth and leaf d13C. Oecologia 140:217-225.

Adams, HD and Kolb TE. 2005. Tree growth response to drought and temperature along an elevation gradient on a mountain landscape. Journal of Biogeography 32:1629-1640.

Baker, MB, Jr. 1986. Effects of ponderosa pine treatments on water yield in Arizona. Water Resources Research 22:67-73.

Baker, MB, Jr., and Ffolliott PF. 1998. Multiple resource evaluations on the Beaver Creek Watershed: An annotated bibliography (1956-1996). USDA For. Serv. Gen. Tech. Rep. RMRS-GTR-13.

Breshears, DD, Cobb NS, Rich PM, Price KP, Allen CD, Balice RG, Romme WH, Kastens JH, Floyd ML, Belnap J, Anderson JJ, Myers OB, and Meyer CW. 2005. Regional vegetation die-off in response to global-change-type drought. PNAS 102: 15144-15148.

Brown, JH, Whitham TG, Morgan Ernest SK, and Gehring CA. 2001. Complex species interactions and the dynamics of ecological systems: long-term experiments. Science 293:643-650.

Hasbargen, J 1994. A Holocene paleoclimatic and environmental record from Stoneman Lake, Arizona. Quaternary Research 42:188-196.

Hargrove, WW, Hoffman FM, and Law BE. 2003. New analysis reveals representativeness of the Ameriflux network. EOS 84:529-535.

Hungate, BA, Dukes, JS, Shaw, MR, Luo, Y, and Field, CB. 2003. Nitrogen and climate Change. Science 302:1512-1513.

Natural Resources Conservation Service Soils Webpage. See: http://soils.usda.gov/

PRISM Group, 2004. Oregon State University. See: http://www.prismclimate.org

Simonin, K. Kolb TE, Montes-Helu M, and Koch GW. 2006. Restoration thinning and the influence of tree size and leaf area to sapwood area ratio on Pinus ponderosa *Laws*. water relations. Tree Physiology 26:493-503.

USGS Southwest Regional Gap Analysis Project, 2004-2005. Land Cover and Animal Habitat Models. See: http://fws nmcfwru.nmsu.edu/swregap/default.htm

Whitham, TG, Bailey JK, Schweitzer JA, Shuster SM, Bangert RK, LeRoy CJ, Lonsdorf E, Allan GJ, DiFazio SP, Potts BM, Fischer DG, Gehring CA, Lindroth RL, Marks JC, Hart SC, Wimp GM, and Wooley SC. 2006. A framework for community and ecosystem genetics: From genes to ecosystems. Nature Reviews Genetics 7:510-523.