CANYONLANDS NATIONAL PARK
RESEARCH SUMMARY 2012

1) Study Title: Mexican Spotted Owl Occupancy: A Measure of Habitat Quality and Productivity in Utah
Permit No.: CANY-2012-SCI-0001
Principle Investigator: Leah Lewis
Purpose of Scientific Study: We propose to combine predictive habitat modeling with occupancy modeling to evaluate how habitat features influence Mexican Spotted Owl demographic parameters such as productivity and probability of site use. We will use a protocol (hooting) surveys to determine occupancy. We will measure geographic, geologic, topographic, and vegetative characteristics at each survey site and collect weather covariates using remote data loggers. Our study will be focused in Zion, Canyonlands, and Capitol Reef National Park in 2012.
Findings/Accomplishments for 2012: The primary goal for the 2012 field season was to measure vegetation and geologic features at historic Mexican spotted owl sites. As such, spotted owl occupancy surveys were not the primary concern and were only conducted opportunistically. A total of 10 Mexican spotted owls were detected at 5 sites (CANY: 2 sites, CARE: 1 site, ZION: 2 sites) of which 5 were male, 3 were female, and 2 were juveniles. Spotted owl pairs were detected at 3 of the sites (CANY: 1 site, ZION: 2 sites) and juvenile owls were detected at 2 of the sites (CARE: 1 site, ZION: 1 sites).
Vegetation and geologic features were measured at 27 sites (CANY: 10, ZION: 7, CARE: 8, BLM: 2). This was accomplished by establishing a 10-meter wide belt across the canyon floor. The belt length was determined by the canyon width and was therefore variable based on canyon size. Total belt lengths varied by canyon and were approximately 5 meters up to 200 meters. Within each belt species and height was recorded for all shrubs and trees. Tree DBH (diameter at breast height) was recorded and binned into 5 classes and canopy cover was measured as presence or absence.
Geologic features were measured along an invisible transect spanning up both canyon walls. Geologic structures were defined as bench, cave, cliff, ledge, overhang, solution cavity, and slope and were measured and counted using a rangefinder and clinometer.
A total of 27 data loggers were deployed across 19 sites (CANY: 5 sites, ZION: 6, CARE: 6, BLM: 2) with some sites having 2 data loggers (one in the floodplain and a paired logger inside of a cave). Three of the 19 data loggers were placed at a ranger station in Canyonlands, Capitol Reef, and Zion Canyon. The data loggers are currently collecting temperature and humidity and have been recording this data since May 2012.
These data are currently being analyzed using various statistical and modeling methods. During 2013 the data will be analyzed using occupancy modeling and species distribution modeling in order to construct predictive habitat models for the Mexican spotted owl. These models will define important spotted owl habitat characteristics across southern Utah.
The pellets that were collected across the 2011 and 2012 field seasons are currently being deconstructed. Diet analysis of these spotted owl pellets will be accomplished during 2013.

2) Study Title: Effects of Climatic Variability and Land Use on American Drylands
Permit No.: CANY-2012-SCI-0002
Principle Investigator: Frank Urban
Purpose of Scientific Study: The American Drylands Project undertakes studies to understand past changes, measure ongoing change, and predict changes in physical and ecological landscapes and how these changes influence landscape stability, ecosystem dynamics, and human communities of American drylands.
Arid and semi-arid lands compose about one half of the lower 48 states and are among the Nation's most sensitive regions to climatic variability and land-use practices. Combinations of natural factors (such as short-term climatic variability) and vastly expanding population, especially in the Southwest, are placing unprecedented pressures on our dry landscapes and their ecological resources. The existing and potential impacts make American drylands a national priority for understanding environmental change and its effects on both human dominated and natural systems. In particular, interactions among land management, societal adjustment, and local to regional planning require contributions and collaborations across many arenas of natural and social sciences.
Examples of key problems include physical impacts of drought and wet periods, ecosystem health (e.g., invasive plant species), human health, water quantity, carbon cycling, and impacts of wildfire. One of the biggest global change issues facing the Nation is the current trend of warming and overall drying of American drylands and models that show exacerbation of these trends during the next few decades (Seager, Science, 2008; NCAR, 2010 http://www.cgd.ucar.edu , link to drought).
This project addresses the urgent need to understand and measure physical landscape change and its influence on ecosystems and the human communities that depend on ecological services such as water, productivity, and landscape stability. On the scale of ecosystems to physiographic regions of American drylands, we will develop new understanding of interactions among physical, biogeochemical, and human systems, and responses of these systems to forcing from climate and demographic change. With this understanding, we will forecast expectable, near-term changes in physical and ecological landscapes. We will provide information, forecasts, and educational materials to federal, state, local, and Native American agencies and communities, for their land-use planning, management of resources, and protection of human health.
In the Canyonlands area these objectives are addressed largely through monitoring of environmental variables and dust deposition at the two CLIM-MET monitoring stations in the park and the two immediately adjacent to the park and at the ISKY regional dust camera near the ISKY ranger station, for monitoring project information see these websites.
http://data.usgs.gov/climateMonitoring/region/show?region=americandrylands
http://esp.cr.usgs.gov/info/sw/clim-met/index.html
Monitoring at these stations has been ongoing since 1998 with close relationships to other USGS research groups (Jayne Belnap, MOAB), University of Colorado (Jason Neff â Previously Assigned NPS study number, CANY-0013, permit number CANY-2010- SCI-0005) as well as longstanding collaboration with NPS researcher/manager Mark Miller.
Findings/Accomplishments for 2012: All sites were visited 2-3 times by USGS personnel in 2012. These site visits typically include onsite checks and calibration of environmental sensors, download of data,

maintenance of instrumentation. Project overview and downloadable environmental data as well as publications listings is available at the following URL's.
http://data.usgs.gov/climateMonitoring/region/show?region=americandrylands
http://esp.cr.usgs.gov/info/sw/index.html
http://esp.cr.usgs.gov/info/sw/clim-met/
http://esp.cr.usgs.gov/info/regional_cams/index.html
Findings from data collected in 2011/2012 were presented at the Canyon Country Science Symposium in Moab, UT in March 2012.
Local and Regional Airborne Dust in the Canyonlands Region: Integrated Analysis of Digital Imagery, Total Suspended Particulate, and Meteorological Data
Frank E. Urban, Richard L. Reynolds, Jason C. Neff, Daniel P. Fernandez, Marith C. Reheis, Harland L. Goldstein, Edmund E. Grote, Chris Landry
Data were presented at the 2012 Fall meeting of the American Geophsical Union in San Francisco, Session ID - A33E-0209
Atmospheric dust in the Upper Colorado River basin: Integrated Analysis of Digital Imagery, Total Suspended Particulate, and Meteorological Data
Frank E. Urban, Richard L. Reynolds, Jason C. Neff, Daniel P. Fernandez, Marith C. Reheis, Harland L. Goldstein, Edmund E. Grote, Chris Landry
Additionally, two additional recent publications that employed data obtained under this permit are listed below.
Reheis, M.C., and Urban, F.E., 2011, Regional and climatic controls on seasonal dust generation in the southwestern U.S.: Aeolian Research, doi:10.1016/j.aeolia.2011.03.008.
Munson, S.M., J. Belnap, G.S. Okin. 2011. Responses of wind erosion to climate induced vegetation changes on the Colorado Plateau. Proceedings of the National Academy of Sciences 108: 3854-3859.

3) Study Title: Population monitoring of humpback and bonytail chub in Cataract Canyon
Permit No.: CANY-2011-SCI-0003
Principle Investigator: Paul Badame
Purpose of Scientific Study: Goals: Maintenance of long term catch rate trend data, longitudinal distributions, and population size structures for humpback and bonytail within Cataract Canyon.
Objectives:

1. Complete one ten day pass each year sampling five sites within Cataract Canyon.
2. Obtain highest possible rates of capture of humpback and bonytail within concentration habitats and maximize number of individuals marked and captured at each sampling site.
3. Determine annual catch rate trend for chubs, examine population size structure, and compare longitudinal distribution to past years.

Findings/Accomplishments for 2012: Annual sampling was conducted October 4-12, 2011 at two long-term trend monitoring sites and at rapid 12 (Figure 1). Daily mean flows ranged from 8,730 - 10,950 ft3/sec (Figure 2) and water temperatures ranged from 17.5 - 13 ºC. No sites were sampled below the Big Drop rapids. The higher than average fall flows precluded sampling at the long-term sampling site located between rapids 2 and 3, as all camp sites were submerged. Trammel nets were the only gear deployed during the 2011 sampling period, equipment malfunctions precluded electrofishing. During

2011 we had irreparable failure of four Smith-Root 5.0 generators. A total of 9 humpback chub were captured in 2011via trammel nets during 366.8 hours of effort. The resulting catch rate for humpback chub was 0.024 humpback chub/net hr. humpback chub trammel net catch rates within cataract canyon remain stable and have shown no significant trend over the last 20 years; fluctuating between 0.010 and 0.035 fish per hour (Figure 3). Two humpback chubs were recaptured from 2005 sampling and both were found within the original Â½ mile sampling site below rapid 5. The two chubs had grown 13 mm and 18 mm over the six year period. All humpback chub caught by trammel nets were adults (>150 mm) with a mean total length of 237.2 mm. The lack of juveniles was expected, as 1â trammel nets are highly ineffective for capturing Gila smaller than 200 mm and electrofishing was not possible. The size structure of adult humpback chubs within Cataract Canyon remains narrowly distributed (Figure 4). No sites have been sampled below the big drop rapids since 2008 and it is unknown if chubs have expanded their range into this section of river. Due to the high site fidelity often observed in humpback chubs it is likely that re-colonization of this recently created habitat would be slow. A total of 116 fish consisting of 12 species were captured by trammel nets in Cataract Canyon in 2010. Humpback chub, Razorback sucker, and Colorado pikeminnow made up 23.2% of the total sample and all native species combined were 31.9% of the total catch. Razorback sucker and channel catfish was the most common native and nonnative species present.

4) Study Title: SHALLOW SEISMIC SHEAR WAVE VELOCITY AT FORMER EARTHSCOPE SEISMOGRAPH STATION R18A IN CANYONLANDS NATIONAL PARK
Permit No.: CANY-2012-SCI-0003
Principle Investigator: James Turner
Purpose of Scientific Study: University of Utah Seismic Stations (UUSS) located across the Colorado Plateau of eastern Utah have been collecting earthquake data for the University of Utah since the late 1960âs, and the national Earthscope project within the last decade. This research was aimed to collect shallow (<100 meters depth) shear-wave velocity (Vs) measurements at each station location using non-invasive surface geophysical methods. This study provides new data for the local subsurface shear-wave velocity structure under each seismograph location, of which one (R18A) is located inside the Canyonlands National Park. The new site-specific Vs data will be incorporated into seismic site response calculations to improve the understanding of earthquake hazards in the eastern Utah region. Seismic shearwave energy travels through bedrock or soil at different rates, and measuring the intrinsic Vs properties of the substrate at each station provides information about the way the ground behaves during strong seismic ground motions. It is currently postulated that the Paradox Formation (subsurface salt deposits) in eastern Utah attenuates seismic energy relative to areas underlain by other bedrock strata. The Earthscope seismic station R18A location in Canyonlands National Park overlais the Paradox Formation salt. We used industry-standard shallow seismic survey methods to measure the Vs structure at the R18A location to test the hypothesis that Paradox Formation salt exhibits stronger attenuation of seismic energy relative to surrounding non-salt strata. These data will be combined with publically available earthquake data from the seismograph array to calibrate ground motions for seismic site response at the R18A location, and will provide new Vs data for underlying geologic units.
Findings/Accomplishments for 2012: At the R18A site, phase-velocity constraints were obtained in the 8-39 Hz frequency band. Resolved fundamental-mode group velocity constraints are available in the

frequency band of 8-10, 16-20, and 30-38 Hz bandwidth windows. Consequently, the velocity inversion was performed with the phase and limited group-velocity constraints.
At the R18A site, shear-wave velocities are strongly constrained to 35-m depth. Shear-wave velocities are strongly constrained to be greater than 1000 m/s at depths greater than 10 m. In contrast, constraints on maximum shear-wave velocities are generally weak for depths greater than 40 m. Regional findings for seismograph sites overlaying Paradox Formation salt are summarized in the table below.

Halite Stations

Earthscope	Vs30 (m/s)	Z1.0 (km)	log10 Vs30
Q18A	1003	0.02	3.00130093
R18A	1042	0.01	3.01786772
R19A	349	0.035	2.54282543
S19A	692	0.02	2.84010609

5) Study Title: Collaborative Research: Fluid Flow and Growth of Active Salt Structures at Decadal Timescales, Paradox Basin - Utah
Permit No.: CANY-2012-SCI-0004
Principle Investigator: Karl Mueller
Purpose of Scientific Study: A broad, interdisciplinary analysis of faults, sinkholes, stream channels and topography of the Needles District in Canyonlands National Park. We seek to define how the landscape shifts in response to movement of rocks towards and into the Colorado River Canyon, how surface and ground water might drive or inhibit the movement, and whether deformation occurs by movement on actively expanding faults and sinkholes, or by gentle warping that is not visible to the naked eye. A much more detailed discussion of the scientific motivation for the study is presented in the attached research proposal.
Findings/Accomplishments for 2012: Fieldwork was aimed at developing a model of groundwater flow and quantifying solute transport. A focus of this was to collect spring and groundwater samples in a transect from the Abajo Mountains, where groundwater is recharged through Beef Basin and into Gypsum Canyon. This is the primary drainage channel network into which groundwater transports solutes taken up from evaporate deposits and deposits them into the Colorado River. Collection of small rock samples from these beds was designed to capture the range of permeabilities, such that bounds might be placed on groundwater flow. Sampling of spring and groundwater was completed for modeling of solute transport, recharge and flow through the strata above evaporites that are considered largely impermeable. We also mapped the locations where groundwater was close to the surface based on soil wetness and the presence of vegetation, in particular cottonwoods in channel networks.
Labwork completed this year includes testing of groundwater samples for total dissolved solids, as well as measuring the proportion of stable isotopes of water, deuterium and oxygen. The results of the stable isotope ratios were compared with values predicted for precipitation from the PRISM model, in order to calibrate results with regional variation in stable isotope composition in precipitation.
Groundwater modeling completed this year is based on developing a 3D model of groundwater flow. Initial models are being used to explore groundwater flow paths and solute transport, in particular flux of total dissolved solids, (i.e. halite). One of the key aspects of the work is to study how topography

might influence groundwater flow. The current version of the model represents the watershed as a homogeneous, isotropic aquifer in 3D. The boundary conditions are head is equal to elevation on the top and along the west side. The bottom is no-flow (impermeable evaporite layer), and the east side of the model is also no-flow (a watershed divide). The solute source is on the bottom layer. The model is transient, with recharge occurring over of the highest 1/3 of the model.
Results of the groundwater studies suggested that spring water sampled at higher elevations has lower values for total dissolved solids than at low elevations. This suggests that salt uptake increases downward, as might be expected as an original premise in our study. This implies upward transport of halite to the surface. Initial sampling results suggest salt is picked up along the top of the Paradox formation and then flows laterally in groundwater. Studies of stable oxygen and deuterium isotopes from samples taken above 2000 meters in elevation are similar to those predicted for precipitation in this region of Utah. This implies that no interaction between rainfall and the Paradox formation occurs above this elevation. In contrast, results of stable isotope chemistry for spring samples taken below 2000 meters in elevation area suggest they are derived from groundwater. This implies that groundwater likely has undergone progressively more lateral transport below these elevations, consistent with large-scale topography.
Preliminary permeameter results from three rock types sampled in the Cedar Mesa Formation that include coarse sandstone, fine sandstone, and limestone suggest considerable variation in conductivity relative to lithology. Initial results suggest the coarse sandstone units (which are so friable they are difficult to core) have conductivities around 10-6 meters per second, whereas the finer grained sandstone has conductivities of 10-9 meters per second. These results were consistent with field observations where springs, seeps and hanging gardens were consistently located at the base of the coarse sandstone unit.

6) Study Title: U.S. Geological Survey Research in Canyonlands NP (NOTE: This is a continuation of previous studies CANY-00013, CANY-00047, and CANY-00048)
Permit No.: CANY-2012-SCI-0005
Principle Investigator: Jayne Belnap
Purpose of Scientific Study: Maintaining native plant communities, biocrusts (composed of cyanobacteria, lichens, and mosses), soil stability and normal water and nutrient cycles in desert systems is critical to healthy ecosystem functioning. These particular ecosystem processes are threatened by climate change (both altered temperature and precipitation), the compressional forces generated by the trampling of people and offroad driving, and invasive plants (especially annual weeds).
Climate change:
Temperatures are expected to rise by up to 6 oC by the year 2100 in this region. Models predict precipitation to show up to a 20% decline. Even with no change in precipitation, higher temperatures will decrease soil moisture by around 30%, stressing plants, biocrusts and altering nutrient cycles.
Compressional forces:
Soil compaction and disruption of biocrusts via trampling can result in decreased water availability to vascular plants through decreased water infiltration and increased albedo with possible decreased precipitation. Surface disturbance also generally causes accelerated soil loss through wind and water erosion, with a concomitant decline in soil fertility, and decreased diversity and abundance of soil biota.

In addition, loss of biocrusts will lower nitrogen and carbon inputs and slow the decomposition of soil organic matter, resulting in lower nutrient levels in associated vascular plants. Cold desert systems are likely to be especially susceptible to these disruptions, due to the paucity of surface-rooting vascular plants for soil stabilization, fewer nitrogen-fixing higher plants, and lower soil temperatures, which slow nutrient cycles.

Invasive annual plants:

Many sites on the Colorado Plateau have been, or are being, invaded by annual weeds. Most of these sites have deep soils and were dominated by perennial grasslands before this invasion. Understanding what factors facilitate invasion; the impact of these invasions on native plants, biocrusts and soil nutrient cycles; and whether sites can recover naturally or need intervention is important in management of these sites.

Desert soils may recover slowly from surface disturbances, especially given the expected reduction in soil moisture which is needed for recovery of soils, plants and biocrusts. Recovery from compaction and decreased soil stability is likely to be very slow. Reestablishment rates for soil bacterial and fungal populations are not known. The nitrogen fixation capability of soil requires at least 50 years for recovery. Recovery of crusts can be hampered by large amounts of moving sediment, and re-establishment can be extremely difficult in some areas. Areas invaded by annual weeds may never recover without restoration efforts.

This project addresses how climate change, land use, invasive of annual grasses and the interaction among these components will affect native plants, biocrusts, and soil nutrient cycling. There are three subsets of studies going on within the park to answer how soils, biocrusts, and plants will respond to 1) climate change/annual grass invasion in grasslands along a land use gradient (Virginia Park-Chesler Park-Squaw Flat), 2) climate change on various dominant shrub and grasses (rainout shelters), and 3) climate change on dust production (BSNE network).

Note: This is a continuation of permit #s: CANY-00124 (CANY-2011-SCI-0008), CANY-00013 (CANY-2010-SCI-0005), CANY- 00047 (CANY-2010-SCI-0017), CANY-00048, (CANY-2010-SCI-0004)

Findings/Accomplishments for 2012:

1) Climate change/annual grass invasion in grasslands along a land use gradient.

In spring and fall we visited 3 grassland sites in the Needles district of Canyonlands to continue long-term data collection of sites for monitoring trends in quantity (cover/frequency) and composition of plants and biological soil crusts and soil nutrient dynamics.

2) Climate change on various dominant shrubs and grasses (rainout shelters)

We visited sites in early summer to monitor changes in vegetation. Sampling included several non-destructive assessments of biomass and growth of plants, recording plant and biological soil crust cover, frequency, and composition. We also inserted resin capsules to measure available plant nutrients. We record continuous data on soil moisture and temperature throughout the year. Samples have been sent for isotopic analysis.

3) Climate change on dust production (BSNE network).

We collected dust from BSNEs (dust collectors) at four sites in spring (March), summer (late June), and Fall (late Oct). Dust amounts ranged from 0.8 to 4.9 grams over the year with amounts increasing from Spring through Fall. Dust levels were 4 times greater at 15 cm than at heights of 50 and 100 cm above the soil surface. Dust declined from 12.5 g to 7.5 g between 2011 and 2012.

7) Study Title: Atmospheric Dust Deposition to Canyonlands National Park (previously study # CANY-00013,permit #CANY-2010-SCI-0005, Belnap)
Permit No.: CANY-2011-SCI-0006
Principle Investigator: Jason Neff
Purpose of Scientific Study: The purpose of installing a total suspended particulate (TSP) sampler at Island in the Sky, Canyonlands National Park is to quantify the transport of windblown dust and to characterize the temporal variations in the chemical composition of this dust. Dust is a major atmospheric contaminant and a primary cause of reduced visibility in National Parks and other Class 1 airsheds. Despite the importance of dust to air quality and visibility, the sources, variability and composition of dust is not well understood. Accordingly, we are proposing the installation of a dust collector at Island in the Sky in CNP in order to develop a long-term dataset on dust deposition to the park. There are many factors that control the emission of dust from arid ecosystems including both land-use and climate. However, in order to better assess the quantity of material that is moved as well as its geochemical composition, we need the ability to regularly collect samples of suspended dust. The proposed sampler will provide a tool for the collection and chemical analysis of dust on a regular timescale and will greatly improve our estimates of dust fluxes to and from Canyonlands NP.
The TSP sampler is a simple instrument that allows for the high volume filtration of suspended particulates. It consists of a 7.0 amp pump motor that is housed in an aluminum enclosure, resembling a large birdhouse. The pump pulls air over the lip of the aluminum enclosure through an 8âx10â filter paper. The physical barrier provided by the lip prevents large objects such as leaves or insects from being collected on the filter but does allow the collection of a large range of particle sizes. In comparison with other common aerosol sampling equipment, such as those used by the IMPROVE network, the TSP is able to collect a more representative sample of suspended dust. Additionally, because the TSP rapidly samples high volumes of air, more concentrated samples can be collected.
The flux of dust from Canyonland ecosystems has important ecological implications. Dust is generated from the wind erosion of surface soils and this process is most extreme in arid and semi-arid ecosystems. Both the removal and subsequent deposition of dust can influence the ecosystem nutrient cycling and productivity. For example, the removal and/or redistribution of surface soils in arid ecosystems have been shown to alter the nutrient composition of surface soils and to influence the heterogeneity in vegetation composition. Additionally, dust exported from the arid southwest can be represent and significant input of materials to downwind ecosystems as far away as the Rocky Mountains.
Findings/Accomplishments for 2012: When desert soils are eroded by wind, a variety of particle size classes can be transferred into the atmosphere including silt sized particles that measure 10-40 microns in diameter. This study, represents a long-term continuous record of total suspended particulate (TSP) concentrations in Canyonlands National Park in Utah. Average annual concentrations of TSP at Canyonlands in 2012 were 90 mg m-3. In comparison annual concentrations of PM<10 microns at this site were well below 10 mg m-3 in 2012. The high concentrations of TSP appear to be the result of regional dust storm events that result in several months of greatly elevated total particle concentrations including multiple two-week periods when TSP concentrations are in excess of 200 mg m-3 in the region.

Evaluation of particle sizes embedded on filters suggests that the median particle size of particles varies between 10 to 40. This work is currently in review at JGR Atmospheres under the title, The role of dust storms in atmospheric particle concentrations in two sites in the western US, by Neff et al.

8) Study Title: REPEAT PHOTOGRAPHY OF CATARACT CANYON AND VICINITY, SOUTHERN UTAH
Permit No.: CANY-2012-SCI-0006
Principle Investigator: Robert Webb
Purpose of Scientific Study: From 1991 through about 1995, our research group matched approximately 270 photographs of the Colorado River in Canyonlands National Park, particularly in Cataract Canyon. Of these, 60 were originally taken during the Brown-Stanton expedition of 1889 and 25 by the 2nd Powell Expedition in 1871. We propose to rematch these photographs and to assess mortality and recruitment information for common species of desert and riparian vegetation along the river corridors.
Findings/Accomplishments for 2012: We finished the work on the Colorado and Green Rivers in 2012.

9) Study Title: Abundance Estimates for Colorado pikeminnow in the Green River Basin, Utah and Colorado.
Permit No.: CANY-2012-SCI-0009
Principle Investigator: Paul Badame
Purpose of Scientific Study: Obtain an accurate (unbiased) and reliable (precise) estimate of the adult population abundance and survival of Colorado pikeminnow that occupy the Green River study area.
Objectives:
1. Complete a minimum of three sampling passes through the five Green River Basin reaches listed to capture sub-adult and adult
Colorado pikeminnow:

a) Green River between the confluence of the White River upstream to the lower end of Whirlpool Canyon (i.e., upper Rainbow Park).
b) White River between the confluence of the Green River upstream to Taylor Draw Dam,
c) Yampa River between Deerlodge Park and Craig, excluding Cross MountainCanyon,
d) Green River from the White River confluence downstream to near Green River, Utah, and,
e) Green River from downstream of Green River, Utah, to the confluence with the Colorado River.

The LFL and CDOW will attempt up to six sampling passes in the Yampa River, in part associated with bass and northern pike removal projects, in order to obtain a more precise and accurate Colorado pikeminnow abundance estimate.
2. Obtain highest possible rates of capture of Colorado pikeminnow within concentration habitats and maximize number of individuals marked and captured on each sampling occasion.
3. Obtain estimates of probability of capture and abundance for Colorado pikeminnow in each of the five reach and for the entire study area. Razorback sucker data gathered concurrently will also be analyzed, mostly related to survival rate estimation.
Findings/Accomplishments for 2012: All expected sampling for this section was completed and the data was forwarded to CSU Boulder for compilation and analysis. Population estimates will be derived and reported in December of 2014 at the end of the 3-year sampling period.

10) Study Title: NCPN Integrated Upland Monitoring in Canyonlands National Park
Permit No.: CANY-2012-SCI-0010
Principle Investigator: Dana Witwicki
Purpose of Scientific Study: The Northern Colorado Plateau Inventory and Monitoring Network (NCPN) of the National Park Service has identified upland ecosystem characteristics, processes, vegetation, and other biota as vital signs to be monitored. Upland monitoring is intended to strike a balance between increasing fundamental understanding of dryland systems and providing managers early warning of undesirable change. It will document the variability in these systems while providing information needed for resource management decisions. Addressing these two goals will be accomplished partly through sampling design and data analysis. Some sites may be selected as representative of large portions of the landscape, others because of their management history. Evaluation of upland monitoring data in relation to other vital signs will facilitate identification of drivers and distinguishing natural from anthropogenic change. Additionally, plot data from this effort will be used in the classification and interpretation of remotely sensed data.
NCPN upland monitoring objectives for selected vegetation types/ecological sites:
1) Determine status and trends in plant communities including:
    -overall species richness (all vegetation types)
    -cover of vegetation by dominant species and life form (all vegetation types)
    -density of shrubs by size class (all vegetation types)
    -basal area and density of tree species (in forests, woodlands, and Gambel oak)
    -canopy closure (in forests)
    -fuel loading (in forests and woodlands)
    -frequency of exotic invasive species (all vegetation types)
2) Determine status and trends in soil stability including:
    -cover of biological soil crusts by morphological group (cyanobacteria, lichen, moss, and undifferentiated crust; all vegetation types)
    -cover of other surface features (litter, rock, bare ground, etc.; all vegetation types)
    -soil aggregate stability (in grasslands, shrublands, and woodlands)
    -canopy-gap size (as an indicator of wind erosion potential; in grasslands and shrublands)
3) Determine status and trends in hydrologic function including:
    -basal-gap size (in grasslands and shrublands)
Findings/Accomplishments for 2012: The NCPN field crew monitored 48 plots in 2012, including 24 grassland, 12 shallow blackbrush, and 12 PJ/blackbrush plots in the Island in the Sky and Needles districts of CANY. 36 plots were newly established. All plots were checked for cultural resources during reconnaissance and again during establishment or revisit. A draft summary report of 2011 data was completed and sent to resource management staff.

11) Study Title: Climatic Cyclicity and environmental interactions in proximal continental basins: Implication for hydrocarbon prospectivity
Permit No.: CANY-2012-SCI-0012
Principle Investigator: Amy Gough

Purpose of Scientific Study: To understand the interactions of the Permian Sediments within the park, in relation to those in the Moab area.
Findings/Accomplishments for 2012: Ten sedimentary field logs were collected from the Permian Cutler Group around Canyonlands National Park, one of which extended into the park itself, near the entrance by The Gooseneck. The logs have been interpreted to assess the change in sedimentological environment from the Arkosic Facies, near Moab, and the Organ Rock Formation and White Rim Sandstone within the park. The project has yet to reach the final conclusions.

12) Study Title: Assessing Climate Refugia and Connectivity for Desert Bighorn Sheep
Permit No.: CANY-2012-SCI-0014
Principle Investigator: Clinton Epps
Purpose of Scientific Study: (Note: the Detailed Implementation Plan for this study has been signed by Kate Cannon, the Superintendent of the Southeast Utah group, and Jeff Troutman, formerly the Resource Management Division Chief for the Southeast Utah group.)
Management of wide-ranging species with fragmented distributions offers a difficult challenge on NPS lands, particularly in the face of regional or global shifts in climate. Desert bighorn sheep (Ovis canadensis nelsoni) exemplify that challenge. This charismatic, desert-adapted animal exists in relatively small, sometimes isolated populations scattered across the arid southwestern United States. Recent research has firmly linked desert bighorn sheep persistence and genetic diversity with climate variation (Epps 2004; Epps et al. 2004, 2006), and reproduction and survival for this species are predicted in large part by precipitation and temperature (Wehausen 2005). However, high rates of population extinction (e.g., Wehausen 1999) may be mitigated by recolonization from other nearby herds (e.g., Epps et al. 2010). While climate is intractable to management at the regional level, maintaining connectivity among existing populations of bighorn sheep will provide the best means for offsetting the unpredictable but potentially devastating changes in precipitation and temperature predicted for the American southwest. Historically, management of desert bighorn sheep was approached on a population by population basis. Growing recognition that desert bighorn sheep are subject to metapopulation dynamics (frequent extinction and recolonization of small populations in discrete habitat patches) has made it clear that desert bighorn sheep must be managed at a regional level. This is particularly true given that many processes that affect bighorn sheep, such as climate variation or climate change, are correlated at regional scales. Human-driven landscape change is also happening at an unprecedented scale, as demonstrated by proposed massive solar developments in the
Mojave Desert and the US-Mexico border fence (Flesch et al. 2010). National Park Service lands support significant populations of desert bighorn sheep in at least nine parks in four states. However, in many cases the connectivity of those populations and with other populations in each region is unclear. Also unclear are the roles of those herds in regional context: are they core populations, peripheral populations, or do they serve as a critical link for gene flow and dispersal between other populations in the region? Lastly, although region-level predictions from global climate change models are often highly variable, how will anticipated changes in temperature and precipitation affect desert bighorn metapopulation structure and habitat?
Despite these uncertainties, ongoing research on desert bighorn sheep has created unprecedented opportunities to evaluate the role of bighorn sheep populations on NPS lands in the context of

metapopulation persistence and climate change. We propose to use a combination of new and existing datasets to 1) analyze genetic diversity and metapopulation structure of desert bighorn on NPS and pertinent surrounding lands; 2) optimize connectivity models by augmenting existing genetic datasets; 3) explore metapopulation persistence under different climate change scenarios; and 4) identify regional refugia for desert bighorn sheep in the context of NPS lands and climate change.
Findings/Accomplishments for 2012: We collected over 900 bighorn sheep fecal samples from NPS lands and adjacent public lands in 2012 for genetic analysis. We genotyped 666 samples (collected in 2012 and previous years) and from these identified 404 unique genotypes (i.e., individuals).
Efforts specific to CANY are as follows:
We collected 63 fecal samples from the following areas: Neck Spring, Pete's Mesa, Shafer Canyon, Alcove Spring Trail, Lathrop Trail, Gooseberry Trail, and Upheaval Dome. We genotyped 62 samples and identified 36 unique genotypes. An additional 48 samples were collected from BLM lands supporting bighorn populations that likely interact with those in the park.
Remaining fecal samples will be genotyped and genetic data will be analyzed, in combination with previously collected/genotyped samples, to reveal genetic structure of desert bighorn sheep populations on and near NPS lands. A spatial database and full report including locations of fecal samples, group sizes and locations of bighorn sheep observations, genetic data, and important waterholes will be provided to NPS at the completion of the study.

13) Study Title: Characterization of Permian White Rim Sandstone in southeastern Utah: Iron oxide concretions, and relationships to fluid flow
Permit No.: CANY-2012-SCI-0015
Principle Investigator: Marjorie Chan
Purpose of Scientific Study: The Permian White Rim Sandstone is a striking, bleached, cliff-forming unit of Wayne and Garfield counties in southeastern Utah. White Rim outcrops of the Elaterite Basin in Canyonlands National Park (CNP) and Glen Canyon National Recreation Area (GCNRA) are well-exposed and show a preserved paleotopographic high. Geologically, the White Rim is a porous, eolian formation with significant bleaching and iron oxide concretions that collectively record the history of iron cycling and fluid flow during diagenesis.
The objectives of this study are to: 1) document diagenetic iron oxide precipitation in the White Rim Sandstone which provides the stunning coloration of the rock and 2) characterize the petrophysical properties (e.g., permeability, porosity, grain size) of the White Rim Sandstone to better understand eolian reservoir properties. Models that explain the genetic linkage of sandstone coloration and iron oxide concretions were developed in other Colorado Plateau rocks, but this White Rim study is unique because it incorporates petrophysical and shows remnants of chemically reducing agents that could have been responsible for sandstone bleaching. Overall, the results of this study will enhance public understanding on the geologic significance of the White Rim Sandstone (e.g., why it is so white and distinctive and how it got that way), and how iron has been nature's artistic pigment over geologic time.
Findings/Accomplishments for 2012: In this Permian White Rim Sandstone study, we examined two major depositional units:1) the lower main eolian unit and 2) the upper marine veneer unit. Through field mapping and observation, we mapped three diagenetic facies superimposed upon the depositional

units: 1) bleached (white colored zones of coloration), 2) diffuse (large-scale zones of red, brown or yellow coloration) and 3)concretionary (zones of clusters of densely cemented sandstone).
Preliminary analysis suggests that there is a genetic relationship between the coloration of the White Rim Sandstone and the migration of a chemically reducing fluid (likely hydrocarbons still in place in the Elaterite Basin) through the reservoir. Petrophysical data indicates that the most permeable intervals lie within the lower eolian unit (vs. the upper reworked veneer unit). The White Rim Sandstone was likely originally red with thin iron oxide coatings that formed around the sand grains during early diagenesis. As the reducing fluid moved through the reservoir, it stripped the iron from the grains, created the bleached facies during iron mobilization and later re-precipitated iron oxide cement it in the diffuse and concretionary facies. This model is supported by diagenetic facies mapping as well as measured section and petrophysical data collected in the field.
Our initial studies thus far indicate that: 1) iron cycling and mobility is dependent upon the sedimentary framework (e.g., bedding, laminae, structures); 2) petrophysical properties have a profound effect on the small-scale (mm to cm) controls of fluid flow through this reservoir; and 3) the White Rim Sandstone coloration records a complex history of diagenetic events.
This characterization study of the White Rim sandstone includes laboratory study of the physical, mineralogic, and microscopic attributes of the rock. Thus far, 43 analyses on field samples including detailed framework and cement mineralogy using QEMSCAN (Quantitative Evaluation of Minerals by SCANing electron micrsocopy), X-ray diffraction, reflected light spectroscopy and thin section petrography, and standard core plugs to calibrate in situ permeability measurements have been conducted. Further analysis will help determine the timing, genesis and processes of diagenetic events in the White Rim Sandstone.
The exposures of sedimentary strata and their prominent sandstone coloration in Canyonlands National Park and the surrounding Glen Canyon National Recreation Area are exceptional in their natural beauty. This study emphasizes multiple geologic events that contribute to the diagenetic history of fluid flow and mineral precipitation over deep time that create striking appearances on the Colorado Plateau. Our project is still in progress and we expect to continue field studies, mapping, stratigraphic sections, sampling, and laboratory analyses throughout 2013.

14) Study Title: Impact of Climate Change on Extreme Floods in the Western U.S.
Permit No.: CANY-2012-SCI-0017
Principle Investigator: Robert Webb
Purpose of Scientific Study: Our research is directed at answering questions relating extreme floods to climate change. Does the paleoflood chronology in the western U.S. indicate increased frequency and magnitude during specific, long-term climate shifts, and do those floods correlate well with the long-term, streamflow record? To develop the chronology, this study will: (1) conduct paleoflood field studies along the Colorado River and major tributaries upstream from Glen Canyon Dam, (2) utilize two geochronology techniques for validating age constraints of paleofloods, and (3) run hydraulic models to estimate the discharge of individual paleofloods. By combining these three methodologies, a robust paleoflood chronology can be developed that will reveal critical information about theoretical questions about extreme hydrologic responses to climate change. Further work will focus on implications for flood

hydroclimatology and flood frequency analyses. Results from this study will be disseminated widely to various state and federal agencies, non-profit groups and floodplain managers.
Findings/Accomplishments for 2012: Field research was conducted at several sites along the Green River, from Turk's Head downstream to the Confluence, and in Cataract Canyon at Tilted Park. Stratigraphic sections of flood deposits were identified and described, and OSL samples were collected for dating analysis.

15) Study Title: Ecological effects of stream drying under climate change in the Upper Colorado River Basin
Permit No.: CANY-2012-SCI-0018
Principle Investigator: Lindsay Reynolds
Purpose of Scientific Study: Streamflows in late spring and summer have declined over the last century in the western US and mean annual streamflow is projected to decrease by six to 25% over the next 100 years. In arid and semi-arid regions of the western US, it is likely that some perennial streams will shift to intermittent flow regimes in response to climate-driven changes in timing and magnitude of precipitation, runoff, and evapotranspiration. We propose to address the following research question: what will be the effects of reduced low flow stream hydrology on riparian plant communities? To address this question we will sample riparian plant communities along a hydrologic gradient (perennial to intermittent) to develop statistical relationships between flow parameters and biotic responses. These statistical relationships can eventually be used to help predict biotic changes under climate change-driven stream drying. Final products will include annual progress reports, a final report, a peer-reviewed manuscript, a final presentation, and an informational, interactive website accessible to land and water managers. The tasks included in this research will be carried out over 2 years, completed by September 2013.
Findings/Accomplishments for 2012: During 2012, we established one study site in Canyonlands National Park: on Salt Creek. At this site we did a topographic survey cross section of the creek bed and surveyed vegetation adjacent to and associated with the wash. We obtained topographic and plant community data, as well as observational hydrologic data. We plan to analyze and write a report including these data during 2013. This final report and associated manuscripts will be completed in late 2013 and early 2014.

16) Study Title: Assessment of Stocked Razorback Sucker and Colorado Pikeminnow Reproduction in the Lower Green River via Larvae and Young of Year Collections.
Permit No.: CANY-2012-SCI-0019
Principle Investigator: Julie Howard
Purpose of Scientific Study: This project targeted determining and monitoring early life stages of endangered fish in the Colorado River drainage, specifically the Colorado pikeminnow (Ptychocheilus lucius) and the razorback sucker (Xyrauchen texanus). Monitoring of the young-of-year (YOY) Colorado pikeminnow was initiated in 1986 within the upper Colorado River basin as part of the Interagency Standardized Monitoring Protocol (ISMP). The ISMP sampling in the lower Green And Colorado Rivers was proposed to monitor recruitment success of first year endangered fishes, to correlate cohort strength and condition to abiotic and biotic parameters, and to provide data for a predictive model

measuring future cohort strength. Since its inception, the ISMP protocol has been updated to refine its scope and methods to focus not only on pikeminnow but all small-bodied fishes allowing for assessment of other projects such as nonnative control actions. A comprehensive synthesis of the effect of changes in physical habitat (as a function of flow and flow variability) and other environmental conditions on the small-bodied fish community (emphasis on Colorado pikeminnow) is underway.

Another aspect of this project is designed as a pilot study to determine the presence/absence of early life stages of endangered razorback sucker in the lower Green River. By the mid 1990's most wild riverine adult razorbacks in the Green River basin were limited to one population in the middle Green River with an estimated size of about 500 adults (Modde et al. 1996). Although sampling from 1992-96 did verify the presence of larval razorback in both the middle and lower Green River it was believed that mortality rates on those larvae were very high and did not provide any significant recruitment into the wild population (Muth et al. 1998). Habitats were identified for razorback sucker larvae as ephemeral shoreline, ponded lower portions of flooded tributary streams, side canyons, washes, canals and channels (Muth et al. 2000). Historic collection sites for larvae were Millard Canyon, the confluence of the San Rafael River, and Green River Valley area. By 2000, wild adult razorback suckers in the Green River Basin were very rare and the few remaining have likely perished (Bestgen et al. 2002). Stocking of hatchery reared razorback sucker in the Green River basin began in 1999 as a means to augment the population and continues through the current time (USFWS 2002). Thus, all current reproduction observed is likely by stocked adults. Determining the reproductive success of stocked fish in the Green River is key to understanding their ability to maintain a viable self-sustaining population.

During sampling for adult Colorado pikeminnow (2001-2003 and 2006-08; UDWR unpublished data), within the lower Green River, the occurrence of adult razorback captures had increased greatly from 9-10 individuals per year to an average of 320 captures between 2006 and 2008. In addition, during the 2007-08 adult pikeminnow sampling an increased number of ripe adult razorbacks have been captured throughout the lower Green River and in two specific locations congregations of ripe razorbacks displaying spawning behavior have been observed and captured. In 2008, three age 1+ razorbacks were captured within the lower Green as well. This progression of events over the last three years strongly suggests that adult stocked razorbacks are now persisting in large enough numbers within the lower Green to facilitate successful spawning. Successful spawning among stocked razorback is an important component of a viable recovery for the species. Determining the timing, locations and relative extent of larval recruitment will help define the success of the recruitment of young suckers into the adult population.

Findings/Accomplishments for 2012: Light trip samples were collected at sites between river miles 199.6 (Saleratus canyon) and 78.9 (Keg Spring Canyon) during five sampling events from the period of 5 May to 1 July 2012. Due to low water during the spring and summer on the Green River (approximately 30% of 112 year average) and in flooded tributaries, sampling was limited to Green River Valley (RM 120), Keg Spring and Tenmile Canyons (RM 78.9 and 80.3, respectively) and the San Rafael River confluence (RM 97) areas. Millard Canyon (RM 33.5) was inaccessible, however, samples were taken from Tenmile Canyon (RM 80.3) and Keg Spring Canyon (RM 78.9), flooded tributaries similar to Millard Canyon. A total of 38 light trap samples were collected and of those, 24 samples were sent to the

CSU larval fish lab for identification. During the study, main channel temperatures ranged from 17.0°C to 22.3°C with a mean of 18.9Â°C. Habitat temperatures ranged from 14.0°C to 24.0°C with a mean of 20.3°C.
The 2011 sample results were received from the CSU larval fish lab in October 2012. In total, 178 light trap samples were collected and 68 were sent to CSU larval fish lab for identification. Razorback sucker larvae were present in 31 of the samples; a total of 165 razorback were identified and were an average of 10.4±2.4mm (5-27mm) in total length. Samples containing razorback larvae were taken from Browns Wash (RM 199.5) to Millard Canyon (RM 33.7).
Seine samples were collected between river miles 92.5 and 23.2 during one sampling trip from 3 July to 5 July. A second trip was attempted from 25 July to 26 July, and samples were collected between river miles 95 and 67.5, however due to equipment malfunction the second trip was forced to take-out at Mineral Bottom (RM 52.2). Low water conditions, as previously mentioned, prevented further sampling in the lower Green River. A total of 968 m^2 was seined and 19 seine samples were collected, 13 of which were sent to the CSU larval fish lab for identification. During the study, main channel temperatures ranged from 23.0°C to 28.0°C with a mean of 26.6°C. Habitat temperatures ranged from 22.5°C to 32.0°C with a mean of 27.2°C.
In 2011, a total of 33 seine samples were collected and 17 were sent to the CSU larval fish lab for identification. Razorback sucker larvae and juveniles were present in six of the samples. A total of 17 razorback were identified and were an average of 38.4±11.7mm (26-62mm) in total length. Samples containing razorback were taken from Upheaval (RM 44) to Dry Lake (101.6) where 58% found in Keg Spring Canyon (RM 78.9).

17) Study Title: Quaternary Paleoecology of the Colorado Plateau (Canyonlands region of SE Utah)
Permit No.: CANY-2012-SCI-0020
Principle Investigator: Mary Allison Stegner
Purpose of Scientific Study: This project will Quaternary-age fossil deposits in Canyonlands NP and the surrounding region of southeastern Utah. Multiple land use types are juxtaposed in this region: Forest Service, National Parks, working cattle ranches (owned by the Nature Conservancy), and BLM land, so the impacts of land use change can be assessed in sites that have essentially the same biotic/abiotic starting conditions and history, but very different present-day uses. I plan to collect end-Pleistocene/Holocene-aged fossil deposits (Neotoma midden and raptor roosts) in order to shed light on small mammal faunal dynamics in the Colorado Plateau region and to develop taxon-free metrics of faunal change that will aid in conservation and management. Our understanding of past environmental and community-level change in western North America would benefit from broader perspective; comparisons between provinces like the Great Basin (which is well-studied) and the Colorado Plateau, for example, could answer questions like: how are differences in climatic regime reflected in the small mammal community? How has connectivity and provincialism between biogeographic provinces changed from glacial to interglacial times?
Findings/Accomplishments for 2012: Aside from surveying for appropriate woodrat middens in the Needles district (none were located), no activity was conducted this report year.

18) Study Title: Long-Term Monitoring of Soil Moisture Dynamics in Response to Climate, Vegetation Patterns, and NPS Restoration Actions
Permit No.: CANY-2012-SCI-0021
Principle Investigator: Michael Duniway
Purpose of Scientific Study: Soil moisture is a key driver of patterns and processes in dryland ecosystems and is affected by climate, soil hydrologic properties, vegetation structure, and land-management activities that alter dynamic soil and vegetation characterstics (McAuliffe 2003, Turnbull et al. 2008). Despite the importance of soil moisture in drylands and its sensitivity both to climate and human land-use activities, methodological limitations have hampered the ability of researchers and managers to affordably monitor soil moisture dynamics at spatial scales most relevant to management. To support NPS management activities in the Salt Creek watershed of Canyonlands National Park, this project proposes to install innovative soil-moisture sensors that overcome past methodological limitations by sensing soil-moisture conditions over a spatial extent of 34 hectares (~ 84 acres). Proposed installations in Canyonlands will be included in a nationwide network known as COSMOS (COsmic-ray Soil Moisture Observing System). COSMOS is funded by the National Science Foundation and monitoring stations provide real-time soil moisture data online (http://cosmos.hwr.arizona.edu/). The purpose of the proposed installations at Canyonlands is to monitor changes in soil moisture conditions in response to climate and restoration actions to be taken by NPS beginning in FY2015. Installation in FY2013 (fall 2012) will allow for two years of pretreatment data to be collected prior to the beginning of the restoration project.
Findings/Accomplishments for 2012: Both sensor stations were successfully installed. Data is available online. Calibration procedures will be performed in 2013.

19) Study Title: Dating the Upheaval Dome Impact Event Using Zircon and Apatite (U-Th)/He Thermochronology
Permit No.: CANY-2012-SCI-0022
Principle Investigator: Cameron Mercer
Purpose of Scientific Study: Though the formation of the Upheaval Dome structure in Canyonlands National Park, Utah, has been heavily debated, several recent studies have provided strong support for an impact origin. In particular, planar deformation features have been reported in quartz grains from the Kayenta Formation exposed at Upheaval Dome, and are considered diagnostic indicators of a meteorite impact. The timing of impact, however, is poorly constrained, with estimates that range from the Middle Jurassic to the Late Miocene. Thermochronology may help to resolve this issue since low temperature thermochronometers may be readily reset by impact heating or subsequent hydrothermal activity. We will use the zircon and apatite (U-Th)/He thermochronometers to date the Upheaval Dome impact event. In detail, we will separate zircon and apatite grains for (U-Th)/He analyses from samples collected from rock units that have previously been shown to contain shocked quartz or that exhibit evidence for aqueous alteration. This may allow us to place precise constraints on the timing of the Upheaval Dome impact event, and will help contribute to our understanding of the impact history of the Earth.

Findings/Accomplishments for 2012: In October 2012, we collected four rock samples from exposures of the White Rim Sandstone, Windgate Sandstone, and the Kayenta Formation at Upheaval Dome. We cut small billets from each sample and have sent them to have petrographic thin sections made for petrologic characterization. The remaining sample materials are currently being processed to separate grains of zircon and apatite for (U-Th)/He dating.