
# GRSM, SHEN, APHN, BLRI Collaborators Meeting – Notes

Date: Wednesday, 11/14/2012

Time: 1:00 – 5 PM (EST)

Location: BLRI Visitor Center (Asheville, NC)

---

## Takehomes from Meeting / To Do's:

**Prioritization of potential project topics**

- **Top priority**
  - Vegetation communities (6-7 linking elevations):
    - spruce fir
    - cove hardwood
    - northern hardwood
    - pine systems
    - oak hickory
    - montane alluvial forest
    - mixed mesophytic
    - balds, beech gaps, hemlock?
  - High elev veg communities
  - PACE methods
  - Land use legacy in the parks
- **Maybe with Partners**
  - ? Watersheds and aquatic species
  - Hydro periods, runoff flashiness, droughts, floods: esp. in context of headwater streams and sensitive species.
  - Invasives (plant and animal), complexities of what is "invasive" in a climate change world.
  - All taxa survey habitat suitability analysis
- **Low priority because outside LCC-VP expertise**
  - Endemic species
  - Wetlands and changes in hydrology

## Takehomes from Meeting / To Do’s (Continued):

**Potential products**

- Vulnerability assessments
- Tree species level models
- Vegetation types (e.g. ecological system types)
- Data sets
  - Exposure (temp, land use)
  - Sensitivity
  - Adaptive capacity
  - Vulnerability
  - Ecosystem process factors (e.g., Lifeform change, Water holding capacity)
- Resource briefs to facilitate LCC-VP communication with parks/partners:
  - LCC-VP Eastern project overview (Patrick/Scott G., Andy, Bill/John/Dave)
  - TOPS resource brief, summarizing variables and datasets (Bill, John, Forrest/Weile)
  - Overview of specifically how vulnerability will be assessed/quantified in eastern study region (Patrick/Scott G., Andy, Bill/John/Dave)
- Climate/exposure summaries for DEWA, SHEN, and GRSM (John, Bill, Patrick)
- Quantification of uncertainty for select variables through LCC-VP / park data integration (e.g., in GRSM to illustrate how driving variables used in project relate to park-level station data)

## Context

Climate and land use changes are occurring at rates that make it challenging to use science to answer pressing management questions. This collaboration is special in that it enables us to conduct new science to meet select management needs. We want to understand:

1. What “top tier” or “high priority” resources do parks see as suffering from a particular lack of scientific information on climate and land use change?
2. What types of data, models, and analyses would help to fill those management-relevant gaps in our scientific knowledge?
3. What specific products are needed to translate the science into information that is useful and meaningful to management?

## Purpose

Develop common understanding of issues and topics that will guide future project activities with parks and other partners in the Appalachian region.

## Scope

Activities and topics that can reasonably be addressed by the project team, including progress in the Great Northern study region, current and proposed plans and projects in the Appalachian region, and other park or partner activities that can contribute to or constrain LCC-VP.

## Outcomes

- All participants understand the general goals of LCC-VP and how these can be used in the Appalachian region.
- Identification and articulation of 1 to 3 resources that LCC-VP will address. These may include species (e.g., eastern hemlock) or ecosystem processes (e.g., net primary productivity)
- Identification and articulation of datasets and models that are required to inform our resource analyses, or may simply be valuable in either raw (e.g., gridded climate forecasts) or summary (e.g., park-specific climate summary reports) form.
- Identification and articulation of other products that would help meet management needs.
- Preliminary schedule for future LCC-VP Appalachian region activities.

## Background

In advance of the meeting, we encourage everyone to quickly read our 10-page LCC-VP overview: https://irma.nps.gov/App/Reference/Profile/2175571 (download PDF under "Holdings"). This document provides a summary of goals/objectives, primary audiences, deliverables, and timelines.

## Participants

- Tony Chang (Montana State University, Graduate Student)
- Tina Cormier (Woods Hole Research Center, Research Assistant)
- Robert Emmott (APHN, Program Manager)
- Patrick Flaherty (APHN, Data Manager)
- John Gross (IMD, Climate Change Ecologist)
- Andy Hansen (Montana State University / Landscape Biodiversity Lab, Professor / Director)
- Patrick Jantz (Woods Hole Research Center, Postdoctoral Fellow)
- Forrest Melton (California State University Monterey Bay / NASA Ames Research Center, Senior Research Scientist)
- Bill Monahan (IMD, Ecologist)
- Nora Murdock (APHN, Ecologist)
- Nathan Piekielek (Montana State University)
- Sarah Reed (Colorado State University / Wildlife Conservation Society, Faculty Affiliate / Associate Conservation Scientist)
- Tom Remaley (GRSM, Ecologist)
- Jim Renfro (GRSM, Air Quality Program Manager)
- Jim Schaberl (SHEN, Chief of Natural and Cultural Resources Division)
- Paul Super (GRSM, Science Coordinator)
- Dave Theobald (IMD, Geographer/Ecologist)
- Jeff Troutman (GRSM, Chief of Resource Science and Management)
- Weile Wang (NASA Ames Research Center, Research Scientist)
- Jeb Wofford (SHEN, Fish and Wildlife Biologist)
- Scott Zolkos (Woods Hole Research Center, Research Assistant)

## Agenda

1:00-1:15 Introductions

1:15-1:30 Overview and updates on progress in the Great Northern (Andy)

1:30-2:00 Preliminary analyses and ideas for Appalachian region and focal parks (Patrick, Tina, Scott)

2:00-4:30 Group discussion focused on these and related questions (with chance for break)

1. What are the expectations and desires from LCC-VP?
2. What's a plausible outcome from our activities that would be viewed as useful or successful, and what project outputs/outcomes do we want to avoid?
3. What "top tier" or "high priority" resources do parks see as suffering from a particular lack of scientific information on climate and land use change?
4. What types of data, models, and analyses would help to fill those management-relevant gaps in our scientific knowledge?
5. What specific products are needed to translate the science into information that is useful and meaningful to management?
6. What do you see success looking like on this project?

4:30-5:00 Summarize meeting and discuss next steps / timeframes / roles / responsibilities (Andy)

5:00 Adjourn

## Meeting Notes

**LCC-VP Introduction / Overview (Andy)**

- Background / context from NASA (funder)
  - NASA Applied Science program – aims to apply data/technology to decision making in new arena
  - Not judged by pubs – but by how decision support has been enhanced
  - Our project: link NASA and NPS, plus other agencies in LCCs
  - Want to involve collaborators early so shape decisions and have vested interest
- Goals / objectives
  - Overall: Demonstrate Climate Change (CC) adaptation planning, in 2 LCCs but with lessons learned for others
  - O1: Hindcast/forecast environmental drivers / responses
  - O2: Assess vulnerability of ecological processes and major habitat types
  - O4: Evaluate management options
  - O5: Work collaboratively with management partnerships to implement management
  - O6: Deliver products and support
- 4 step framework
  - ID management targets
  - Conduct Vulnerability Assessments (VA's)
  - ID management options
  - Implement management decisions

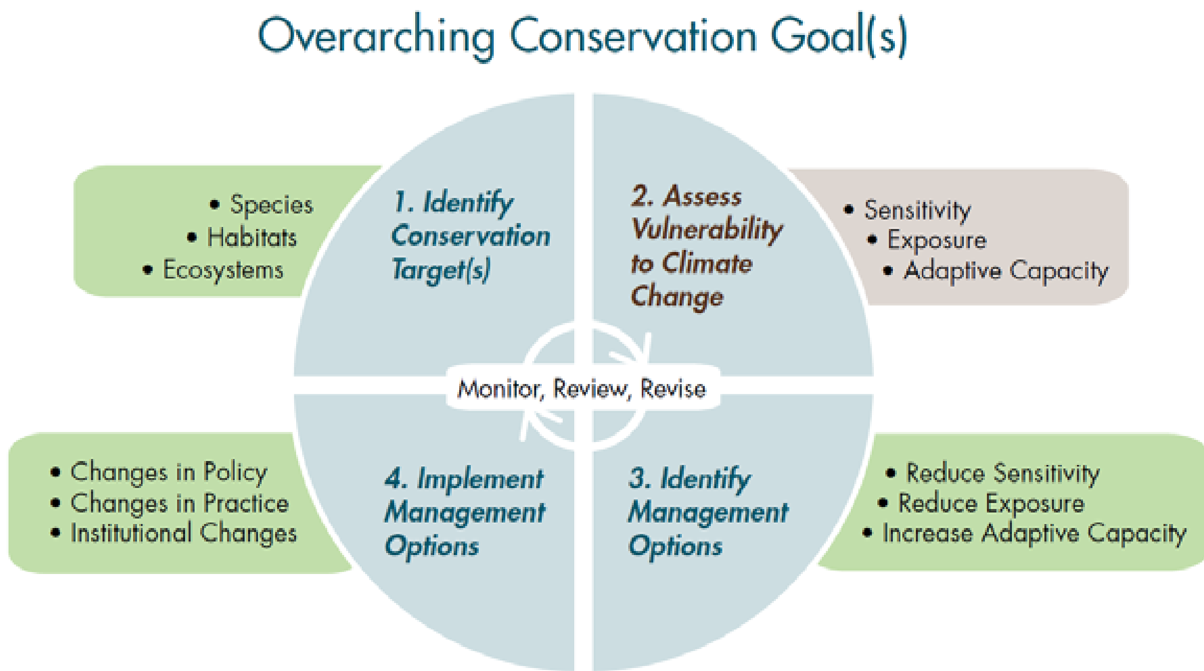



Figure 1.1. Framework for Developing Climate Change Adaptation Strategies

**Glick et al. 2011**

- Want to provide case studies of approach to then try and apply more broadly (other geographies)
- Step 1: ID management targets (this mtg = start)
    - Selecting the targets to get at vulnerability
    - Similar to that done in late July for YELL and GRTE, but less formal
    - Want to leave here today with short list (4-5) topics that we can focus on in LCC-VP
- Step 2: Compute Vulnerability
    - VA framework (from Glick et al. 2011)
    - Exposure + Sensitivity > Potential impact + Adaptive capacity > Vulnerability
    - Use strong science to get at exposure and sensitivity
    - Use more expert (park) knowledge to get at adaptive capacity
    - Data to consider:
        - Exposure: Forrest's climate and TOPS data/variables (snow, runoff, soil moist, fire, npp, phenology)
        - Exposure: Dave's Land use
        - Adaptive Capacity: Connectivity models from Dave and Scott G.
    - Biodiversity – step back and focus on a coarser, major habitat, level
        - Ultimately, consider life history stages in niche models; use other regional efforts (e.g., Hargrove) to look across LCCs
        - At park/PACE scale, want to integrate other local data (e.g., park veg, soils, or climate data)

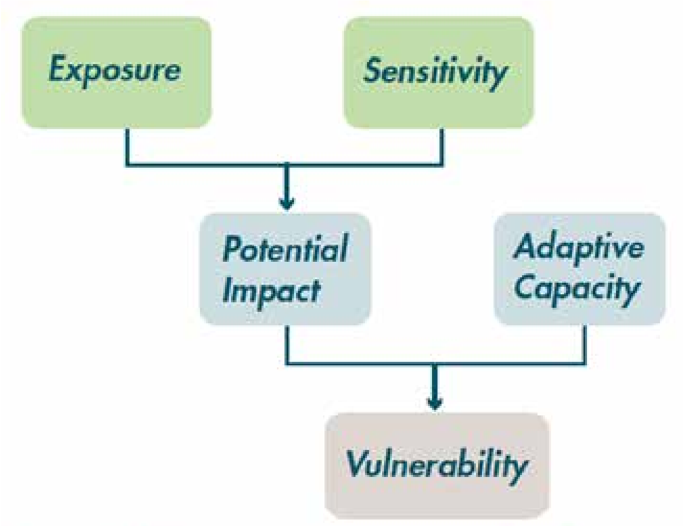
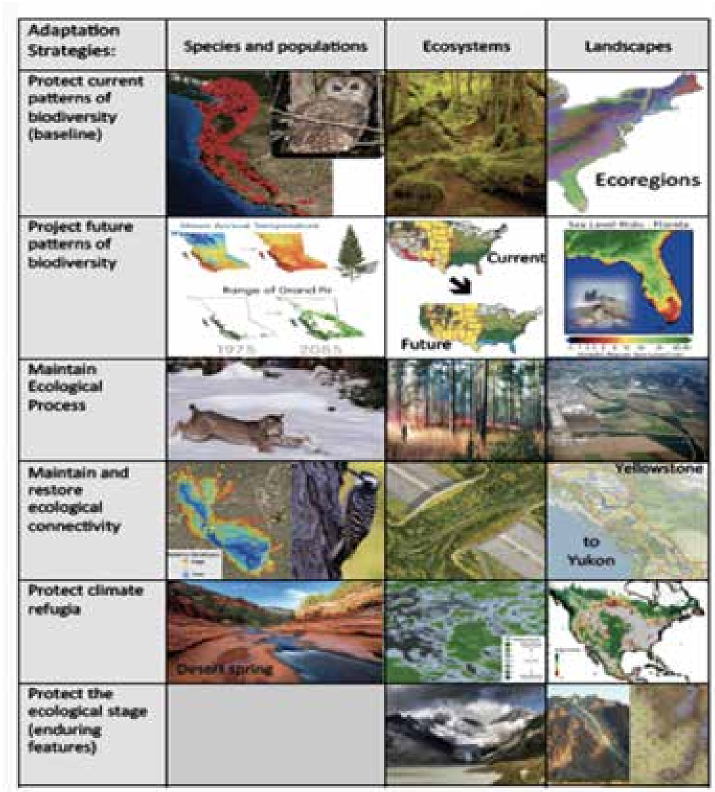


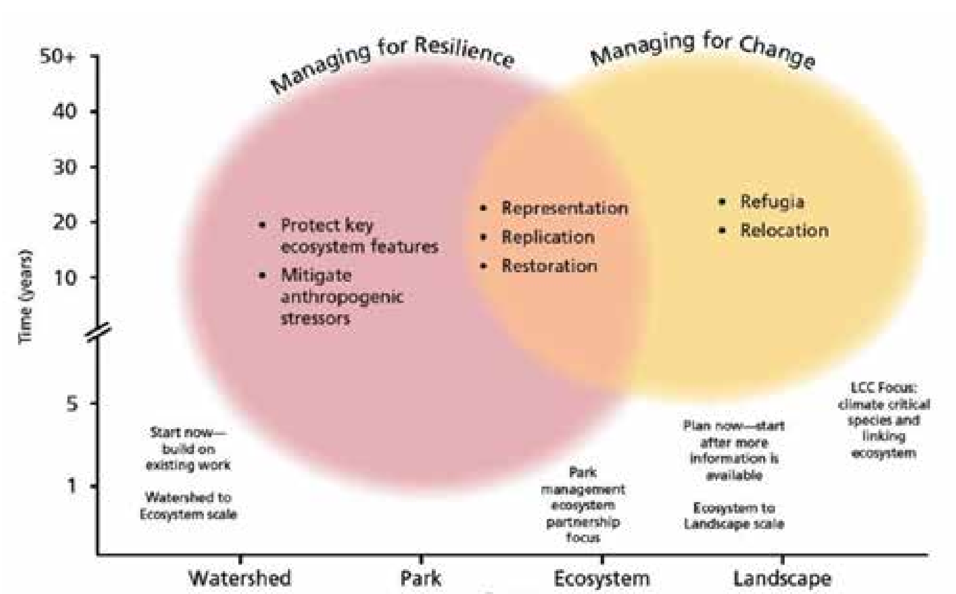

Figure 2.1. Key components of vulnerability, illustrating the relationship among exposure, sensitivity, and adaptive capacity.

**Glick et al. 2011**

- Step 3: Identify Management Options from VA
  - Ex: WBP reproducing at lower elevation, but not growing to adult status (being outcompeted by more shade tolerant conifers?). Interest in seed sources for different planting zones (e.g., elevationally). Or how might we treat competing vegetation to bolster WBP?
  - Yale framework to think about CC management strategies
  - Multi-agency/institutional groups
  - Message: a variety of strategies that we need to be thinking about, from spp to ecosystems to landscapes
- Step 4: Facilitate management decisions
  - Help assess management feasibility
  - Consider: Low risk vs. manageable vs. save at all costs
  - Help deliver management strategies across space/time scales
- LCC-VP Timeline
  - Currently Month 3 of Year 2; will go through 4 years
  - Idea to start ALCC in year 2




**Yale Framework: One possible paradigm for identifying management options (from Dave Theobald)**




**Spatiotemporal scales to consider for implementation (from Tom Olliff)**

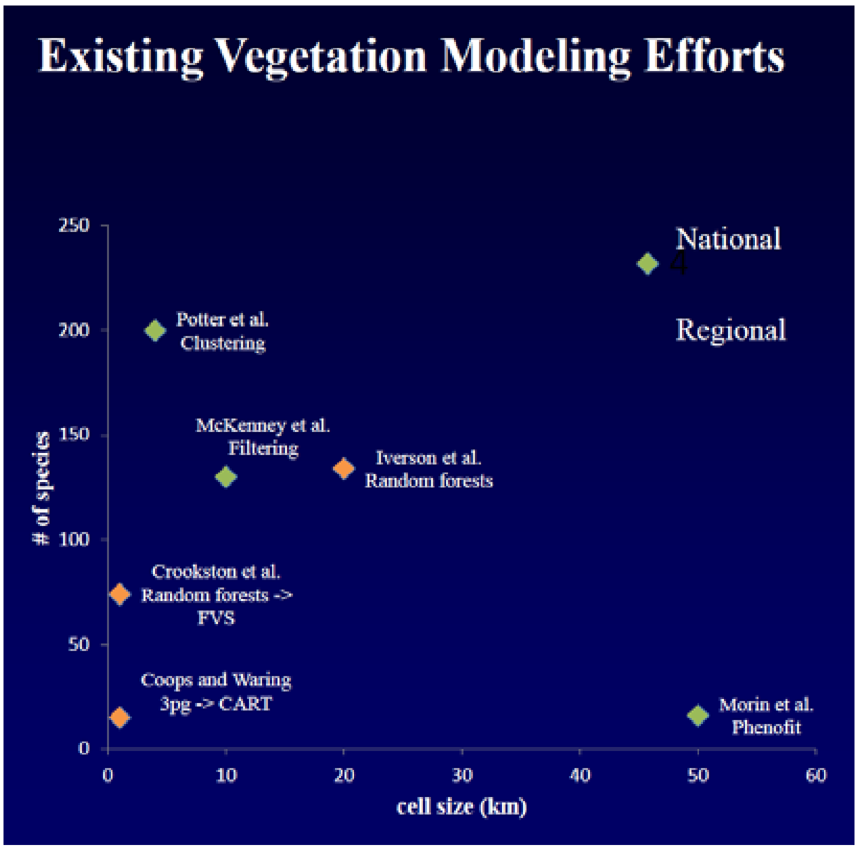
## Questions?

Jim S: What are the products?

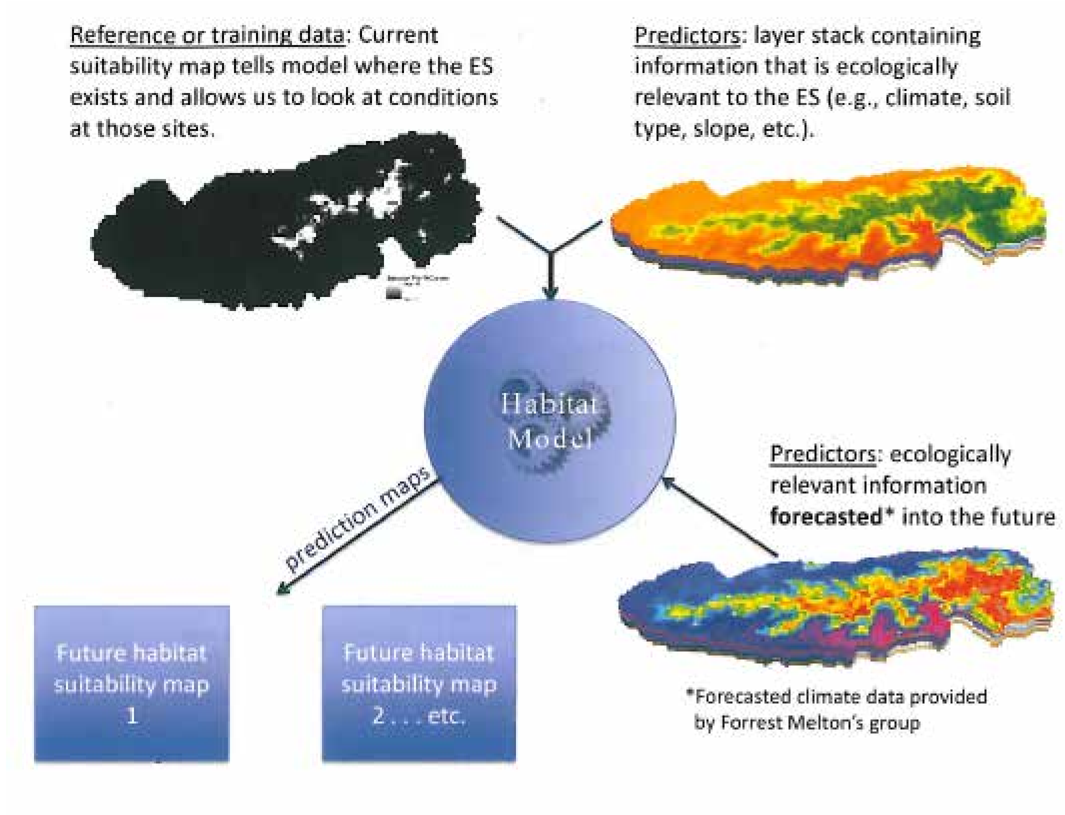
John: We can separate the outcomes and products; products = all the data, analyses, and syntheses (e.g., resource briefs). Outcomes = designing products that are timely for parks and other partners

**Introduction / Overview of Eastern LCC-VP Efforts to Date (Patrick)**

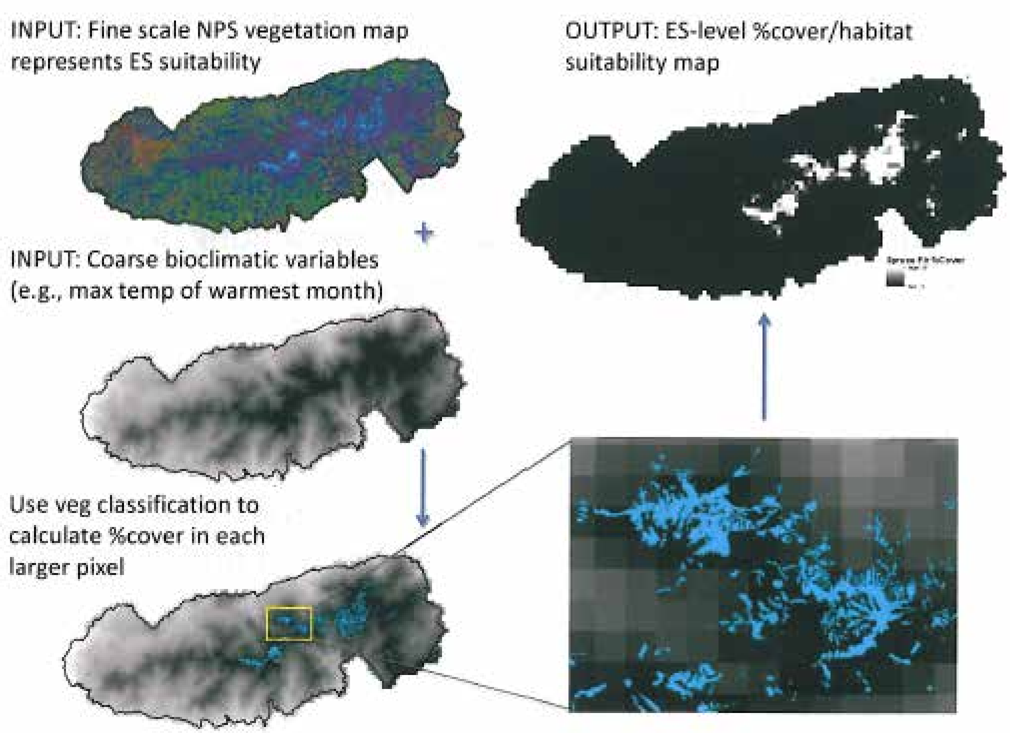
- Summarize literature on other tree modeling studies/databases (for ALCC general region)
  - Hargrove
  - Iverson
  - McKenny
- Zoom in to park scale and for 4-5 ecol systems (groups of co-occurring species) model at high res responses to climate and land use change – integrate park data. 800 m starting res, then further scale to ~30 m
- What ecological system types are interesting? Have thoughts but looking for guidance from partners
  - Spruce fir
  - Cove forests
  - Northern hardwood forests




**Existing modeling efforts relevant to ALCC regions (from Patrick Jantz)**




**Conceptual overview of how niche or habitat models are built (from WHRC)**




**Conceptual overview of how model predictions are interpreted across spatial scales (from WHRC)**

**Discussion (Organized by Topic & Extended to Include Additional Notes on Available Data)**

- **SHEN / GRSM / APHN and ALCC interests**
  - High elevation communities & endemics (mtn top scale). E.g., Shenandoah salamander climate change adaptation study (endemic on talus slopes; total range of 6,000 ac only in SHEN)
  - Multiple scales of riverine systems (watersheds and large rivers): Fate of brook trout – emphasis on rarity; stream temperature
  - Hydroperiod and flow
  - Frequency of storm events flashiness and how they will be changing
  - Hydrology – likely better addressed by others, but LC-VP could provide e.g. TOPS data / models
  - Perhaps reflecting some bias from ALCC participants, but do reflect big concerns for SHEN (many high elevation openings, often not very large)
  - Mountain-top scale – connectivity and survival. In SHEN, many of these are balds, rocky outcrops and the like. Many of these are not spruce-fir
  - Wetlands – many are small and thought to be vulnerable
  - Invasive species – plants, insects, diseases – relative threats (SHEN: still in reactive state and want to use models to become more proactive)
  - At least 3 major airshed modeling efforts for GRSM for different pollutants over the last 15yrs – EPA, states others?
  - APHN 1-pager on climate change (***see final page***): High elevation communities, Vulnerable aquatic and riparian ecosystems, water quality and quantity
  - Target a specific wildlife spcs to follow through CC and LUC trajectories with ecol. consequences and planning framework etc. (e.g., Shenandoah salamander: funded project to think about adaptive management already?)

- **Invasives**
  - Can we model ‘invasive species’ and ID species that will likely no longer be invasive in the future?
  - Andy: NPSpecies analysis / slide (many eastern parks show up with largest number of invasives (relative to ~70 NPS units / PACEs in Lower 48)
    - GRSM: interested in seeing development and temperature trends over same 50 yrs (so bars are synchronized both spatially and temporally)
  - SHEN: Also interested in native/invasives in the future that will exert particularly large effects on existing species/systems
  - High elevation challenges: largely pest (HWA) vs. climate related? For spruce, hemlock, fir – HWA distribution – life cycle under climate control

- **Scaling issues / considerations**
  - Scaling is a persistent issue in space, time, and theme (level of classification detail)
  - Questions regarding how far out beyond park boundaries PACE’s go. For more information on PACEs, see the NPS PALMS website: [http://science.nature.nps.gov/im/monitor/lulc/palms/](http://science.nature.nps.gov/im/monitor/lulc/palms/)

- GRSM: Interested in getting PACE themes into park GIS database – access
- Articulating airsheds? I.e., is there an air equivalent of PACE? Different for each pollutant, source, geography, etc (3 major efforts to do this for select systems – N, Sulfur, C, Mercury)
- LCC-VP Communities: want to span elevational range to encompass high, low, and mid elevations (for ~complete geographic coverage and to evaluate possible turnover at ecotones/boundaries)

- **Species / Habitats / Ecological System Types to Consider**
  - Spruce fir, cove hardwood, northern hardwood, pine systems, oak hickory, mixed mesophytic, montane alluvial forest (small but important), and possibly hemlock (HWA moving west) and beech gaps
    - GRSM: Hard to know which of these might be the best "one" to start with, but maybe hypothesize change / vulnerability and look to a coarse scale first to prioritize (e.g., ecological system VAs).
    - SHEN: Might also look to examples that seem to be limitied (e.g., elevationally, latitudinally)
    - Species sensitive to climate = largely unknown. LCC-VP might use Bill Hargrove's approach to ID broad scale range shifts in tree species to guide future work. Also use these to look at broader potential dispersal zones for each of two LCC study regions
  - Hemlock is still in western and far northern portions of LCC but HWA have killed it mostly elsewhere (southern and eastern parts of range). SHEN has lost ~95% of hemlocks and they are treating on tree-by-tree basis. Southern Appalachians have two species and Carolina hemlock is an endemic.
    - HWA is to some extent temperature limited this might explain why doing better in northern portion of its range
    - HWA not strong fliers, spread is often from mtn tops to others coincident with wind events
  - APHN: Some papers on how fire suppression in the south/east has resulted in a shift from oak to other species less valuable as food sources for a wide range of species (e.g., decline of fire-dependent species such as red oak that produce key food resources for black bear).
  - Had 2-yr extreme drought the effects of which they are only seeing now several years later – old tree mortality time-lagged opening large gaps that are even savanna-like

- **Working approaches / considerations**
  - Include all NPS staff who are interested in the vulnerability assessment activities (assessing exposure, sensitivity, and adaptive capacity; combine using models to evaluate potential impact and vulnerability)
  - Do periodic conference calls
  - Do two expert panels on vulnerability assessment
  - How do we do outreach to the broader set of stakeholders that will be interested in the project?
  - GRSM: Many other parks/networks that will be interested in at least base products

## NPS and Other Park-level Data Summary

11 Inventories found

| Unit Code | Inventory | Products | Status | Year Begin | Year End |
|---|---|---|---|---|---|
| GRSM | Soil Resources (SRI) | 0 | Complete | 2008 | 2009 |
| GRSM | Air Quality Related Values (AQVI): Nutrient Enrichment Effects | 5 | Complete | 2010 | 2011 |
| GRSM | Base Cartography (BCI) | 2 | Complete | 2001 | 2010 |
| GRSM | Vegetation Mapping (VMI) | 2 | Complete | 1999 | 2004 |
| GRSM | Geologic Resources (GRI) | 1 | Complete | 2006 | 2006 |
| GRSM | Air Quality Related Values (AQVI): Acidification Effects | 2 | Complete | 2010 | 2011 |
| GRSM | Climate (CLI) | 1 | Complete | 2006 | 2007 |
| GRSM | Natural Resource Bibliography (BIB) | 0 | Complete | 2000 | 2008 |
| GRSM | Baseline Water Quality (WQI) | 2 | Complete | - | 1995 |
| GRSM | Air Quality Data (AQI) | 1 | Complete | 2004 | 2006 |
| GRSM | Water Body Location and Classification (WBI) | 0 | Complete | - | 2000 |

Available from https://irma.nps.gov/App/InventoryTracking

11 Inventories found

| Unit Code | Inventory | Products | Status | Year Begin | Year End |
|---|---|---|---|---|---|
| SHEN | Air Quality Related Values (AQVI): Nutrient Enrichment Effects | 5 | Complete | 2010 | 2011 |
| SHEN | Base Cartography (BCI) | 1 | Complete | 2001 | 2010 |
| SHEN | Vegetation Mapping (VMI) | 4 | Complete | 2000 | 2009 |
| SHEN | Air Quality Related Values (AQVI): Acidification Effects | 2 | Complete | 2010 | 2011 |
| SHEN | Climate (CLI) | 1 | Complete | 2005 | 2006 |
| SHEN | Baseline Water Quality (WQI) | 1 | Complete | - | 2000 |
| SHEN | Geologic Resources (GRI) | 1 | Complete | 2009 | 2009 |
| SHEN | Natural Resource Bibliography (BIB) | 0 | Complete | 2000 | 2008 |
| SHEN | Air Quality Data (AQI) | 1 | Complete | 2004 | 2006 |
| SHEN | Water Body Location and Classification (WBI) | 0 | Complete | - | 2000 |
| SHEN | Soil Resources (SRI) | 0 | Not Scheduled | - | - |

Available from https://irma.nps.gov/App/InventoryTracking

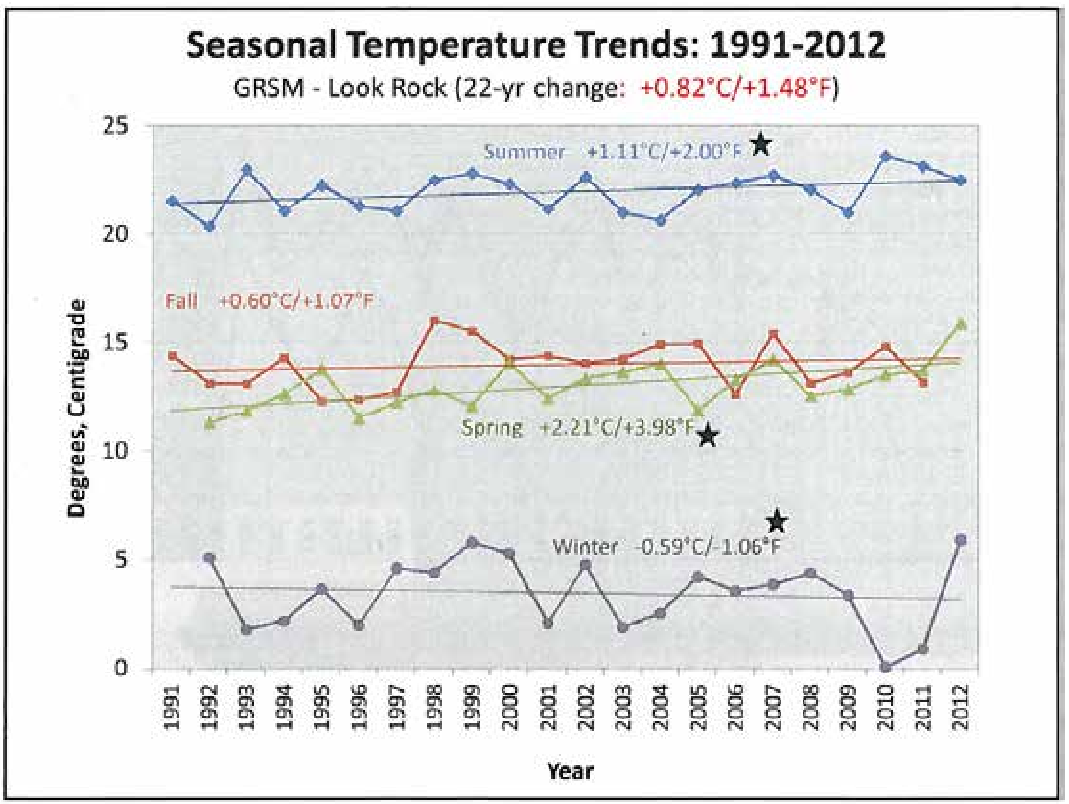
11 Inventories found

| Unit Code | Inventory | Products | Status | Year Begin | Year End |
|---|---|---|---|---|---|
| DEWA | Vegetation Mapping (VMI) | 3 | Complete | 2001 | 2007 |
| DEWA | Air Quality Related Values (AQVI): Nutrient Enrichment Effects | 5 | Complete | 2010 | 2011 |
| DEWA | Base Cartography (BCI) | 2 | Complete | 2001 | 2010 |
| DEWA | Air Quality Related Values (AQVI): Acidification Effects | 2 | Complete | 2010 | 2011 |
| DEWA | Geologic Resources (GRI) | 16 | Complete | 2008 | 2008 |
| DEWA | Soil Resources (SRI) | 0 | Complete | 2010 | 2011 |
| DEWA | Natural Resource Bibliography (BIB) | 0 | Complete | 2000 | 2008 |
| DEWA | Climate (CLI) | 1 | Complete | 2005 | 2006 |
| DEWA | Baseline Water Quality (WQI) | 1 | Complete | - | 1995 |
| DEWA | Water Body Location and Classification (WBI) | 0 | Complete | - | 2000 |
| DEWA | Air Quality Data (AQI) | 1 | Complete | 2004 | 2006 |

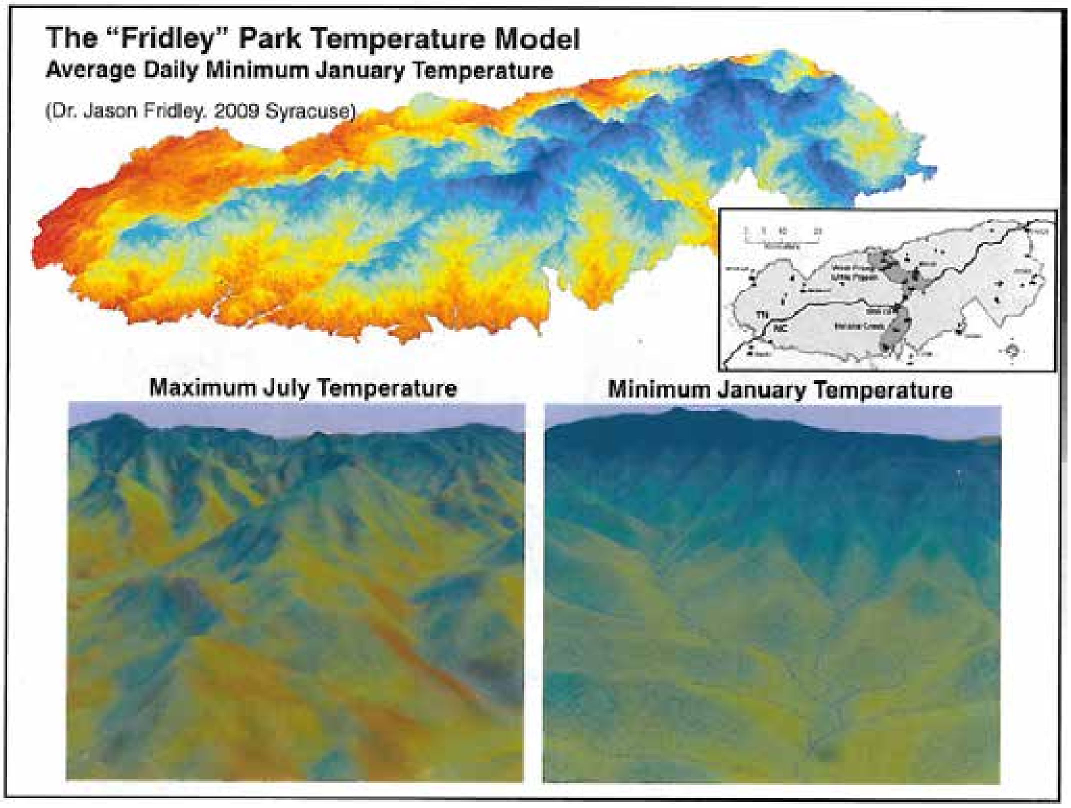
Available from https://irma.nps.gov/App/InventoryTracking

- Additional data from GRSM
  - Gaseous pollutants (http://12.45.109.6/data.aspx)
  - Acid deposition (NADP) (http://nadp.sws.uiuc.edu/)
  - Mercury deposition (MDN) (http://nadp.sws.uiuc.edu/mdn/)

- Dry deposition (CASTNet) (http://java.epa.gov/castnet/)
- Visibility and particulate matter (IMPROVE) (http://vista.cira.colostate.edu/views/)
- Webcam/realtime data: http://www2.nature.nps.gov/air/WebCams/parks/grsmcam/grsmcam.cfm)
- ~70 met stations – possibly use in assessing uncertainty in LCC-VP gridded climate data (need to discuss use of NPS IMD weather station database)
- Fine scale (30 m?) tmin and tmax mapping (Dr. Jason Fridley, Syracuse University)
- ATBI and associated Maxent models – possibly use in a resource priority screening




**From GRSM**




**From GRSM / Jason Fridley (Syracuse University)**

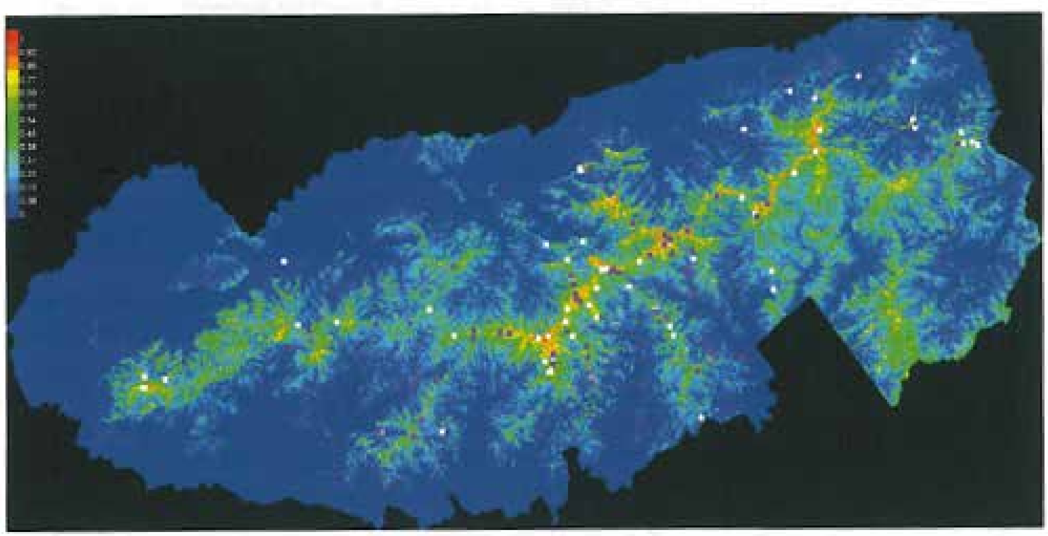


**Figure 31.** Example of a high elevation species distribution in the park, the red-cheeked salamander (*Plethodon jordani*), which is endemic to the park. Prepared by B. Zank, GRSM GIS Specialist, using MaxEnt (freeware, Princeton University) 2009. Lower densities are represented by blue, and higher densities by red.

**From GRSM Conceptual Plan for Vital Signs Monitoring**

**NASA TOPS / NPS I&M (Division) Data and Model Summary**

- Climate – Current/historical (800 m PRISM; 1895-2010; monthly tmin, tmax, tmean, precip, dewpt)
- Climate – Future projected (800 m from CMIP5 models; 2006-2100; monthly tmin, tmax, tmean, precip). 4 scenarios: Representative concentration pathways (RCPs) 2.6 (low radiative forcings), 4.5, 6.0. and 8.5 (high forcings) W/$m^2$. Individual climate models available for each RCP (and used in ensembles – vary somewhat by RCP):
    - rcp26 models: bcc-csm1-1, bnu-esm, canesm2, ccsm4, cesm1-cam5, csiro-mk3-6-0, fgoals-g2, fio-esm, gfdl-cm3, gfdl-esm2g, gfdl-esm2m, giss-e2-r, hadgem2-ao, hadgem2-es, ipsl-cm5a-lr, ipsl-cm5a-mr, miroc-esm, miroc-esm-chem, miroc5, mpi-esm-lr, mpi-esm-mr, mri-cgcm3, noresm1-m
    - rcp45 models: access1-0, bcc-csm1-1, bcc-csm1-1-m, bnu-esm, canesm2, ccsm4, cesm1-bgc, cesm1-cam5, cmcc-cm, cnrm-cm5, csiro-mk3-6-0, fgoals-g2, fio-esm, gfdl-cm3, gfdl-esm2g, gfdl-esm2m, giss-e2-h-cc, giss-e2-r, giss-e2-r-cc, hadgem2-ao, hadgem2-cc, hadgem2-es, inmcm4, ipsl-cm5a-lr, ipsl-cm5a-mr, ipsl-cm5b-lr, miroc-esm, miroc-esm-chem, miroc5, mpi-esm-lr, mpi-esm-mr, mri-cgcm3, noresm1-m
    - rcp60 models: bcc-csm1-1, ccsm4, cesm1-cam5, csiro-mk3-6-0, fio-esm, gfdl-cm3, gfdl-esm2g, gfdl-esm2m, giss-e2-r, hadgem2-ao, hadgem2-es, ipsl-cm5a-lr, ipsl-cm5a-mr, miroc-esm, miroc-esm-chem, miroc5, noresm1-m
    - rcp85_models: access1-0, bcc-csm1-1, bcc-csm1-1-m, bnu-esm, canesm2, ccsm4, cesm1-bgc, cesm1-cam5, cmcc-cm, cnrm-cm5, csiro-mk3-6-0, fgoals-g2, fio-esm, gfdl-cm3, gfdl-esm2g, gfdl-esm2m, giss-e2-r, hadgem2-ao, hadgem2-cc, hadgem2-es, inmcm4, ipsl-cm5a-lr, ipsl-cm5a-mr, ipsl-cm5b-lr, miroc-esm, miroc-esm-chem, miroc5, mpi-esm-lr, mpi-esm-mr, mri-cgcm3, noresm1-m
- Other TOPS Climate variables: Vapor Pressure Deficit, Shortwave Radiation
- TOPS Vegetation and Ecosystem Process variables: Water stress factor, Gross primary productivity, Net primary productivity, Snow, Runoff, Fire, Soild moisture, Phenology
- Protected Area Centered Ecosystems (PACEs) for focal NPS units in study regions. For additional background, see http://science.nature.nps.gov/im/monitor/lulc/palms/docs/pubs/HansenAJ_etal_2011_PACE_BioScience.pdf.
- Land Use model (~70 classes of land use, as opposed to land cover); at 30 m resolution? (D. Theobald)
- Spatially Explicit y Regional Growth Model (SERGoM) – changes in housing densities through time (1970-2100, by decade; 100 m cells). (D. Theobald)
- Landscape connectivity (http://onlinelibrary.wiley.com/doi/10.1111/j.1755-263X.2011.00218.x/abstract) (D. Theobald)
- Past/present changes in human population totals and densities by County and Census block-groups (1790-c. 2050). Available from http://science.nature.nps.gov/im/monitor/npscape/

- Road densities, distance from nearest road, and roadless natural areas for all and major (interstates and highway) roads. Available from http://science.nature.nps.gov/im/monitor/npscape/
- Land cover, land cover change (2001-2006) and impervious surface at 30 m resolution. Available from http://science.nature.nps.gov/im/monitor/npscape/
- Landscape pattern (patch size distributions, morphological spatial analysis [core, edge, bridge, etc], and area density) – possible to calculate on any land cover/habitat/species observations or models. Methods described at from http://science.nature.nps.gov/im/monitor/npscape/
- Conservation context (surrounding land ownership and level of protection). Available from http://science.nature.nps.gov/im/monitor/npscape/

## High Elevation Communities

APHN parks are situated in one of the most species-rich temperate regions on earth, and protect over 400 species ranked by The Nature Conservancy as Globally Imperiled or Vulnerable, including 27 Federally-listed Threatened or Endangered species. Positioned at the tops of the parks' highest mountains are 7 cold-adapted, endemic communities with many rare species that cannot survive warmer climates. GRSM and BLRI contain 85 percent of all the Fraser fir forests (classified as one of the most critically imperiled ecosystems in the U.S.) that remain in existence. These mountain-top communities, usually shrouded in fog for much of the year, are especially vulnerable to climate disruptions that involve significant warming or shifts in precipitation toward drier conditions. Climate monitoring in APHN parks is centered on maintaining data collection from historic weather stations, some of which have a 90-year period of record. Future plans call for independent arrays of small, remotely deployed recording instruments to obtain accurate onsite measurements in long-term monitoring plots.

**BLRI and GRSM contain over half of the highest elevation mountains in eastern North America**

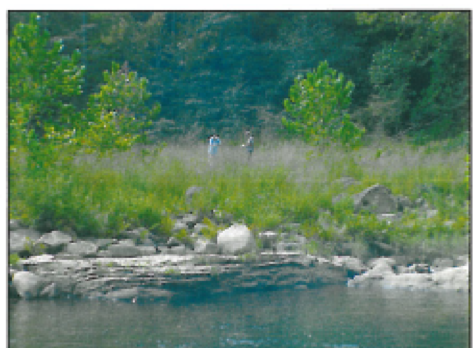
## Vulnerable Aquatic and Riparian Ecosystems

BISO, with 13 Federally-listed Endangered aquatic species, contains some of the most imperiled freshwater fauna in the NPS system. In addition, BISO and OBRI protect the best remaining examples of a globally imperiled river scour prairie community, the Cumberlandian cobble bar, of which fewer than 500 acres remain in existence. At BLRI and GRSM, mountain wetlands support many boreal relict species, as well as rare species endemic to the Southern Appalachian Mountains, all of which are dependent upon a constant supply of cold groundwater. BLRI protects more than 50 percent of what remains of the globally imperiled Southern Appalachian bog/fen habitat type. Extended droughts or any significant disruption of groundwater flow could exterminate these ecosystems, along with the species dependent upon them. APHN is developing protocols for monitoring rare mussels and fish, as well as monitoring the community structure and composition in cobble bar communities, at BISO and OBRI.

**The Big South Fork of the Cumberland River is home to one of the most diverse assemblages of freshwater mussels in the United States (BISO)**

## Water Quality and Quantity

If climate change predictions are borne out, the aquatic systems in APHN parks will likely experience a decline in precipitation, particularly in spring and summer, and a rising number of intense storm events. In rivers and streams, these changes will reduce the amount of available aquatic habitat during sustained low flow periods, and substantially increase the exposure of aquatic organisms to pollutants, most of which are transported during storm events. A major issue for both BISO and OBRI is upstream water withdrawal, for residential and industrial use. Climate change, in combination with population increases, particularly in the upper OBRI watershed, will likely mean that competition for available water will intensify. Network staff are monitoring streamflow and a suite of water quality parameters, including aquatic macroinvertebrates, in all network parks.



**The Cumberlandian cobble bar, an imperiled grassland habitat that is dependent upon scouring floods for survival (BISO, OBRI)**

**Contact Information:** Robert Emmott, Appalachian Highlands I&M Network Program Manager, 67 Ranger Drive, Asheville, NC 28805; robert_emmott@nps.gov; phone 828-407-5657.