FOCUS 3: UNDERSTANDING IMPACTS OF CLIMATE CHANGE THROUGH ECOSYSTEM MODELING AND VULNERABILITY ASSESSMENT

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Montana State University

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University of Montana
**EPSCoR Science**

**Goals:**

1) Develop the conceptual approaches, quantitative tools, and science and management teams to assess the vulnerability under future climate and land use change of:
   - ecosystem processes
   - vegetation composition
   - vegetation phenology

2) Explore the resiliency and adaptive capacity of these ecosystem properties under alternative climate adaptation strategies.
SCIENCE COLLABORATORS

**Hansen Lab, MSU**
Nate Piekielek, Linda Phillips, Tony Chang, Regan Nelson, Erica Garrouthe, Katie Ireland

**Whitlock Lab & IoE**
Todd Kipfer, Virginia Ignalis, Liz Shanahan

**Running Lab, UM**
Jared Oyler, Ashley Ballantyne, Kelsey Jencso, Michael Sweet

**Helen Naughton**

**Jeff Morisette, Dennis Ojima, NCCSC**
Hansen Lab, Whitlock Lab MSU, Running Lab, UM

**Barry Noon, Susan Skagan, Colorado State University and USGS**
Bill Lauenroth Lab, University of Wyoming, Diane Debinski Lab, Iowa State University

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**Tom Olliff, NPS / Great Northern LCC**
John Gross, Bill Monihan, NPS I&M
Dave Theobald, Conservation Science Partners
Forest Melton, NASA Ames
Scott Goetz, Woods Hole Research Center
AGENCY COLLABORATORS

**Western US**
- Great Northern LCC, Tom Olliff
- NPS I&M Greater Yellowstone Network, Kristen Legg
- NPS I&M Rocky Mountain Network, Mike Britten
- Greater Yellowstone Coordinating Committee Whitebark Pine Subcommittee, Karl Buermeyer and Virginia Kelly
- Grand Teton National Park, Kelly McClosky
- Yellowstone National Park, Ann Rodmann
- Rocky Mountain National Park, Ben Bobowski

**Eastern US**
- NPS I&M Appalachian Highlands Network, Robert Emmott
- NPS I&M Eastern Rivers and Mountains Network, Matt Marshall
- NPS I&M Mid-Atlantic Network, Jim Comiskey
- Delaware Water Gap National Recreational Area, Richard Evans and Leslie Morelock
- Great Smoky Mountains National Park, Jim Renfro
- Shenandoah National Park, Jim Schaberl
LANDSCAPE-SCALE 1948-2012
CLIMATE DATASETS FOR MONTANA

Jared Oyler, Steve Running, Ashley Ballantyne, Kelsey Jencso, Michael Sweet
University of Montana

Objective
Produce a topographically-informed spatial climate dataset of Tmin, Tmax, Prcp, Srad, and Humidity
• 1948 – present, daily timestep, 30-arcsec resolution (~800m)
• Supports historical analyses and operational products
• Accounts for elevation, terrain position, water bodies, land cover

See Oyler et al. poster
LANDSCAPE-SCALE 1948-2012
CLIMATE DATASETS FOR MONTANA

Summary and Future Work

- TopoWx is a statistical framework for generating landscape-scale climate data in support of ecosystem research and resource management.

- TopoWx advantages over similar products: incorporation of remote sensing data to better quantify landscape-scale temperature patterns, homogenization of station records, and quantification of uncertainty.

- TopoWx has already been used within the state in support of climate impact studies on snowshoe hares, moose, and aquatic species.

- TopoWx will be extended to estimate humidity and solar radiation so MODIS remote sensing models are more applicable to single watersheds.

- TopoWx is fully open for future community-driven improvements.

TopoWx data will be used to greatly improve ecologic/hydrologic remote sensing products for the state.
Adaptation Planning Approach
## Link with Collaborators and Assess Needs

<table>
<thead>
<tr>
<th>Organization</th>
<th>Key Collaborators</th>
<th>Date</th>
<th>Needs We Can Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater Yellowstone Coord</td>
<td>Virginia Kelly, Karl Buermeyer, Dan Reinhart, Nancy Bokino, Kristin Legg</td>
<td>April 2012, March 2013, Aug 2013</td>
<td>Effectiveness of “GYCC WBP Strategy” under future climate</td>
</tr>
<tr>
<td>Comm Whitebark Pine Subcomm.</td>
<td></td>
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</tr>
<tr>
<td>Grand Teton NP</td>
<td>Sue Consolo Murphy, Dave Hallac, Virginia Kelly, Kristen Legg, Kelly McClosky, Kathy Mellander, Dan Reinhart</td>
<td>July 2012, May 2013</td>
<td>Multiple</td>
</tr>
<tr>
<td>Rocky Mountain NP</td>
<td>Ben Bobowski, Judy Visty, Jeff Connor, John Mack, Larry Gamble, Jim Cheatham, Mary-Kay Watry, Nate Williamson</td>
<td>Nov 2012</td>
<td>Climate, land use, ecosystem interactions, Limber pine, Collaborative management among agencies</td>
</tr>
<tr>
<td>Great Smoky Mt NP</td>
<td>Jim Renfro, Jeff Troutman, Tom Remaley, Jim Schaberl, Paul Super, Jeb Wofford</td>
<td>Nov 2012</td>
<td>Vegetation comm (6 across elevation range), PACE methods, Land use legacy in parks</td>
</tr>
<tr>
<td>Shenandoah NP</td>
<td></td>
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<tr>
<td>App. Highlands I&amp;M</td>
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<tr>
<td>Delaware Watergap</td>
<td>Rich Evans, Mathew Marshall, Leslie Moorlock</td>
<td>Nov 2012</td>
<td>Hemlock vegetation community, Land use / hydrology</td>
</tr>
</tbody>
</table>
Assess Vulnerability

- **Exposure**: magnitude & extent of change experienced
- **Sensitivity**: degree to which fitness/process is affected
- **Adaptive capacity**: coping responses of species/process
Synthesize Current Knowledge on Vulnerability

Key Climate Patterns and Ecological Consequences: GYE PACE

Temperature Anomaly (1900-2100)
1900-2010: 800-m PRISM
2010-2100: CMIP5 Ensemble Average, RCP 6.5 and RCP 8.5

<table>
<thead>
<tr>
<th>Climate Variable</th>
<th>Trend</th>
<th>Change since 1900</th>
<th>Projections for 2040s</th>
<th>Projections for 2080s</th>
<th>Source¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Ave. ann PTA¹</td>
<td>+2.0°C / 100 yrs</td>
<td>+3.9 (+2.5 to +5.9)</td>
<td>+6.7 (+3.8 to +10.4)</td>
<td>Haas 2010</td>
<td></td>
</tr>
<tr>
<td>Precipitation Ave. ann % rel to 1970-1999</td>
<td>+0</td>
<td>+7 (-2 to +34)</td>
<td>+10 (-12 to +36)</td>
<td>Haas 2010</td>
<td></td>
</tr>
<tr>
<td>Moisture Index PPT/PET¹</td>
<td>-0.4 mm / 100 yrs</td>
<td>Haas 2010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Deficient PET-ARE % rel to 1970-1999</td>
<td>+31%</td>
<td>UW Climate Impacts Group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Snow Pack April SWE % rel to 1970-1999</td>
<td>-20% lower than 500-year average</td>
<td>-34%</td>
<td>Peterson et al. 2011</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. LANDSCAPE CLIMATE CHANGE VULNERABILITY PROJECT August 2015
Synthesize Current Knowledge on Vulnerability

Great Northern LCC - Projected Biome Shift

Data from Rehfeldt et al. 2012
Synthesize Current Knowledge on Vulnerability

Exposure of US National Parks to Land Use and Climate Change 1900-2100

Goal: Illustrate the initial steps in an assessment of vulnerability to land use and climate change for the network of US National Parks

Objectives:
1. Define the surrounding Protected Area Centered Ecosystem (PACE).
2. Quantify past exposure.
3. Quantify potential future exposure and potential impact.
4. Consider implications for management.

Synthesize Current Knowledge on Vulnerability

1900-2000

Synthesize Current Knowledge on Vulnerability
New Science on Vulnerability
Ecological Forecasting

Methods: TOPS

<table>
<thead>
<tr>
<th>Inputs</th>
<th>United States (1km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impervious surface area</td>
<td>SERGoM (Theobald et al., 2009) + NLCD ISA (2000)</td>
</tr>
<tr>
<td>Climate (baseline run)</td>
<td>PRISM 800m Monthly TOPOMET Weather Surfaces</td>
</tr>
<tr>
<td>Climate (forecast)</td>
<td>Downscaled CMIP5 Ensemble averages for RCP 2.6, 4.5, 6.0, 8.5 CCSM-4 scenario</td>
</tr>
<tr>
<td>Elevation</td>
<td>National Elevation Dataset (resampled to 800m)</td>
</tr>
<tr>
<td>Leaf Area Index (baseline run)</td>
<td>MODIS MOD15A2 LAI (Myneni et al., 2000)</td>
</tr>
<tr>
<td>Leaf Area Index (forecast)</td>
<td>MODIS LAI Climatology</td>
</tr>
<tr>
<td>Soils</td>
<td>U.S. STATSGO2 database</td>
</tr>
<tr>
<td>Land Cover</td>
<td>MODIS MOD12Q1 Land cover (Friedl et al., 2002)</td>
</tr>
<tr>
<td></td>
<td>LPJ?</td>
</tr>
</tbody>
</table>
New Science on Vulnerability

Ecological Forecasting

Methods: Climate Downscaling

Statistical downscaling: Bias-Correction Spatial Disaggregation (BCSD)

CMIP5
RCP 2.6 4.5 6.0 8.5
800 m

More info at: http://gdo-dcp.ucirln.org/downscaled_cmip3_projections
New Science on Vulnerability
Ecological Forecasting

TOPS Outputs

**Climate**
- Maximum Temperature
- Minimum Temperature
- Average Temperature
- Precipitation
- Vapor Pressure Deficit
- Shortwave Radiation

**Vegetation**
- Water stress factor
- Gross primary productivity
- Net primary productivity
- Respiration (Maintenance, Heterotrophic)

**Hydrology**
- Outflow
- Evapotranspiration
- Soil water potential (another indicator of vegetation water stress)
- Snow water equivalent
- Soil moisture (VWC)

**BGC Biome Types**
- Grasses
- Shrubs
- Savannah
- Broadleaf evergreen forest
- Broadleaf deciduous forest
- Needleleaf evergreen forest
- Needleleaf deciduous forest
- Unvegetated
- Urban (masked)
New Science on Vulnerability

Glacier PACE 2006 - 2100

Ensemble Average: Summer

Snow-water Equivalent

Soil Water

Runoff

Gross Primary Productivity
New Science on Vulnerability

Whitebark Pine in GYE

Overview
• Keystone species
• High adult mortality
• Listed as candidate species
• Grizzly bear relisted

Management Questions
• Range change under future climate?
• Settings allowing reproduction?
• Where to focus treatment of competitors, translocation?


Key Collaborators
GYCC WBP Subcommittee
New Science on Vulnerability

WBP Adults (>8” dbh) Projected under averaged CMIP5 GCM Climate

Current  RCP 4.5 2100  RCP 8.5 2100

Probability of presence

Present probability histogram

Projection 2100 probability histogram

Projection 2100 probability histogram
New Science on Vulnerability

Grassland Phenology in the GYE

Research Questions:
1. What is the relationship between climate/weather and grassland phenology?
2. What are the spatial and temporal dimensions of green grasses in the Upper Yellowstone River Basin?
3. How does land use modify grassland phenology from its natural state?

Products:

A= April 6; B=May 1; C=June 2; D=Aug 13
Assess Vulnerability Via Expert Panels

An expert panel will use the synthesis of current studies and new science as a basis for ranking vulnerability of key ecological processes and vegetation communities in early 2014.

Ecological hindcasting and forecasting

Diagram:
- Exposure
- Sensitivity
- Potential Impact
- Adaptive Capacity
- Vulnerability

Expert panel
Climate Adaptation Management

We will work with agency collaborators to develop, evaluate, and implement management strategies for vulnerable elements.

### Evaluate Management Options

<table>
<thead>
<tr>
<th>Low Risk</th>
<th>Manageable</th>
<th>Save at High Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management</td>
<td>None needed</td>
<td>Helpful</td>
</tr>
<tr>
<td>Exposure</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Vulnerability</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Resiliency</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Adaptability</td>
<td>High</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

### Develop Implementable Management Strategies

- Protect key ecosystem features
- Mitigate anthropogenic stressors
- Representation
- Replication
- Restoration
- Refugia
- Relocation

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*NSF EPSCoR Track-1 EPS-1101342 (INSTEP 3)*
# Climate Adaptation Management: Example

**Goal:** Evaluate potential success of WBP Strategy under future climate.

**Challenge:** Agencies / land allocation types differ in tolerance to management.

<table>
<thead>
<tr>
<th>Greater Yellowstone Ecosystem</th>
<th>Agency/Allocation</th>
<th>Legal Direction/Mgt Philosophy</th>
<th>WBP Restoration Tools allowed or likely</th>
<th>% WBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Forests</td>
<td>• Multiple use</td>
<td>All</td>
<td>• Planting seedlings/sowing seeds</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>• Ecological integrity</td>
<td>• Pruning</td>
<td>• Wildland and prescribed fire use</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Targeted fire suppression</td>
<td>• Mechanical thinning</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Research/Monitoring</td>
<td>• WBP</td>
<td></td>
</tr>
<tr>
<td>NF – Wilderness Area</td>
<td>Most actions prohibited or discouraged</td>
<td>Wildland fire use</td>
<td>Research/Monitoring</td>
<td>54%</td>
</tr>
<tr>
<td>NF – Inventoried Roadless Areas</td>
<td>Actions less restricted but remoteness an issue</td>
<td>Planting seedlings/sowing seeds</td>
<td>Wildland fire use</td>
<td>Research/Monitoring</td>
</tr>
<tr>
<td>Yellowstone National Park</td>
<td>Park Service Policy: “Take no action that would diminish the wilderness eligibility of an area” AND/BUT “Management actions...should be attempted only when knowledge and tools exist to accomplish clearly articulated goals.”</td>
<td>Wildland fire use</td>
<td>Research/Monitoring</td>
<td>10%</td>
</tr>
<tr>
<td>Grand Teton National Park</td>
<td></td>
<td></td>
<td>• Planting seedlings/sowing seeds</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Pruning</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Wildland fire use</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Research/Monitoring</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** See Hansen et al. poster.

**Whitebark Pine Strategy for the Greater Yellowstone Area**

Prepared by the Greater Yellowstone Coordinating Committee
Whitebark Pine Subcommittee

May 31, 2011
Design and Deliver Adaptation Strategies

Approach: Simulate potential outcomes of alternative management options:
• Evaluate current WBP Strategy against forecasts.
• Create two additional options that require new agency tolerances.

<table>
<thead>
<tr>
<th>Climate Scenarios</th>
<th>WBP Management Options</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Action</td>
</tr>
<tr>
<td>RCP 4.5</td>
<td></td>
</tr>
<tr>
<td>RCP 6.0</td>
<td></td>
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<tr>
<td>RCP 8.5</td>
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</tbody>
</table>
Potential Activities for 2013-2014

Science Activities

• Extend TopoWx to estimate humidity and solar radiation so MODIS remote sensing models are more applicable to single watersheds.

• Statistical distribution modeling of 5 additional vegetation types;

• Complete GYE phenology studies;

• Develop, validate, apply LPG-GUESS as dynamic vegetation simulator for regional scale applications (with Ben Poulter, Katie Ireland, Steve Running);

• Convene a vegetation modeling workshop (Sept 21, MSU);

• Conduct studies of ecological response to drought across Montana and the NC CSC domain;

• Prepare proposal to NASA for US/Canada Rockies and international vulnerability assessments of protected areas.

Decision Support Activities

• Convene expert panel for vulnerability assessment;

• Co-host a symposium of conifer forest response to climate change;

• Prepare results as NPS resource briefs;

• Highlight resource briefs as webinars;

• Document methods as NPS Standard Operating Procedures

• Continue to publish policy reports such as: Olliff et al. In Prep. Responding to climate change in the NPS Intermountain Region: A Guide to Developing Park-based Adaptation Strategies. Natural Resource Report NPS/IMRO.
Acknowledgements

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