TITLE: Lichen responses to experimental temperature and CO₂ treatments and implications for using the FHM/FIA Lichen Communities Indicator for climate change monitoring.

LOCATION: Marcell Experimental Forest, Minnesota

DATE: September 2013

DURATION: 2014 would be year 1 of a 2 year project

FUNDING SOURCE: base

PROJECT LEADER: Sarah Jovan, Forest Inventory and Analysis Program, Lichen Indicator Advisor, 503-808-2070, sjovan@fs.fed.us

COOPERATORS: Bruce McCune & Peter R. Nelson, Department of Botany and Plant Pathology, Oregon State University.

FHP SPONSOR/CONTACT: Joseph O'Brien, FHP North-Central Region, 651-649-5266, jobrien@fs.fed.us

PROJECT OBJECTIVES: Our main objective is to document lichen species growth and mortality in response to simulated climate change. This project is high value at low cost because it utilizes the high-tech infrastructure provided by Oak Ridge National Laboratory and the USFS Northern Research Station and Marcell Experimental Forest for application of temperature and CO₂ treatments. This work will provide a mechanistic basis for interpreting lichen community monitoring results from the FHM/FIA Lichen Communities Indicator. There already exists a large dataset of over 8,000 epiphytic lichen surveys (1998-2013) across U.S. forests, including many repeat measurements. Use of these data for climate assessment has so far been cursory. Direct measurements of change, as proposed for this study, are critical for developing scientifically defensible climate change bioindicators.

We propose a multi-agency research collaboration (DOE, USFS, Oregon State University) within the SPRUCE experiment (Spruce and Peatland Responses Under Climatic and Environmental change https://mnspruce.ornl.gov/) to study the response of epiphytic lichens to simulated climate change. The lichen study has 2 phases: phase 1 detects the lichen’s transient acclimation response (2 year duration) while Phase 2 detects long-term changes (5 and 10–year durations). This proposal seeks funding for Phase 1, which consists of 3 components:

1. Change in Target Lichen Growth in Response to Climate Change: We would conduct a transplant experiment to investigate how warming and CO₂ treatments affect growth of a common boreal lichen, *Evernia mesomorpha*. This species has a similar distribution to black spruce; both are near their southernmost limit at the SPRUCE experimental site, making populations in this area more sensitive to changes in climate. This fruticose (shrub-like) species has a single point of attachment to the substrate and is soft, non-brittle, making it conducive for use as a transplant. Changes in the abundance and mass of *E. mesomorpha* transplants would be used as coarse but efficient measure of overall lichen growth response to climate change to predict range shifts and abundance of this species across MN, WI and the broader northeast region under different climate warming scenarios and CO₂ levels.

2. Lichen community response to climate change: We installed branch transects in summer 2013 on *Picea mariana* branches (see Methods) within the SPRUCE experimental enclosures and collected baseline data on lichen species covers. These would be remeasured after years 1 and 2 (Phase 1) and years 5 and 10 (Phase 2) once the experiment is turned on (spring 2014). Lichen communities
are scored non-destructively by visual observation of permanent 30-50 cm long transects (modified from McCune et al. 2000) marked by red polyester threads on branches. On each transect, we score cover of all lichens by species to the nearest 1% cover. Analysis of these data will focus on the null hypotheses that, under each experimentally altered climate scenario, (1) no differences in community composition (2) no loss of boreal species, (3) no gains of temperate species. We postulate three classes of mechanisms for changes in lichen communities: direct climatic effects, indirect effects of tree vigor (e.g. more shading induced by growth increases of the host tree could result in the loss of shade intolerant species), and indirect effects of tree mortality.

3. **Lichen climate change index:** We would use lichen community changes observed within SPRUCE’s experimental enclosures (# 2 above) to interpret and predict regional-scale change using FHM/FIA lichen data collected between 1994 – 1999 in MN and WI (n = 136 plots). During year 1 we will evaluate the suitability of the existing FIA lichen community data for establishing a regional climatic lichen dataset centered on Marcell Exp. For. If these data are not sufficient, in year two we will read additional lichen plots on a belt transect from southern Illinois to Ontario, passing through Marcell. We would also install additional FHM/FIA lichen plots in black spruce bogs near the experimental enclosures to bridge between experimental data and existing FHM/FIA community data and/or our belt transect regional lichen dataset. The main end products for the entire 2 year project are: 1) identification of sensitive climate indicator species, 2) development of 1 or more lichen-based indices for monitoring climate change, and 3) analysis of community-climate relationships in MN, WI.

**JUSTIFICATION:**

a. **Linkage to FHM program:** This work provides an empirical basis for using the FHM/FIA Lichen Community Indicator to monitor climate change effects on forest ecosystems. Results will help identify indicator species and the speed of species turnover, if any.

b. **Significance/Impact of forest health issue:** Development of strategies for detection, adaptation, and mitigation of climate change effects is a top priority of all land management agencies. This project would help develop a sensitive, cost-effective indicator for detection.

c. **Scientific basis:** Lichens are highly sensitive to climate because they lack a vascular system to prevent desiccation, which means basic metabolic processes are closely tied to ambient temperature and moisture. For lichens, community-level and species-level responses to climate have been demonstrated in several studies (Ellis 2013, Ellis et al. 2007) and we are starting to also understand effects at the physiological level. However, almost no studies actually measure changes over time and little work has been done for U.S. forest ecosystems. The project leader and lead cooperators have extensive experience working with the FHM/FIA lichen indicator data. The lead cooperators was the primary developer of the lichen community indicator (McCune et al 1997).

d. **Cost/Economic efficiency:** This project is a bargain. 1) We are utilizing the multimillion dollar infrastructure of the high-tech, realistic SPRUCE field experiment at no cost, 2) there is potential for synergy with other research projects also utilizing SPRUCE, 3) we already collected baseline data on community transects and deployed transplants, 4) results will increase value of the extensive database of FHM/FIA lichen data.

e. **Priority issues:** Climate change- long-term effects on forests

**DESCRIPTION**

(a-Background): Our study is uniquely leveraged because it is part of a state-of-the-art climate warming experiment called SPRUCE, headed by the DOE Office of Biological and Environmental Research. Eight-meter tall open-topped chambers will be used for ten different temperature (0 to 9 ºC above ambient)
and two CO₂ level (enriched and ambient) combinations starting in spring 2014. A core team from Oak Ridge National Laboratory and an international group of independently funded researchers will study impacts of variable temperature and CO₂ concentrations to a wide range of biotic and geophysical processes using the same research platform. The overall goal is to facilitate collaboration to answer cross-cutting scientific questions.

Our proposed project addresses climate change effects on forest organisms, their ecology, and vulnerability. We focus on epiphytic lichens, conspicuous but understudied components of forest ecosystems that are known to have key roles in food webs and comprise a large portion of the year-round macroscopic biodiversity. Furthermore, epiphytic lichens are expected to be highly sensitive to climate change, based on observational studies and their complete nutritional dependence on atmospheric sources of water and nutrients. Lichen species shifts have never been examined in a controlled experimental setting at the scale of the SPRUCE experiments. Our study area, an ombrotrophic *Picea mariana*-peatland in northern Minnesota (Marcell Exp. For.), represents a widespread ecosystem of exceptional importance to climate change science because large C stocks stored as peat can be mobilized as CO₂. Understanding critical temperature and CO₂ thresholds for lichens helps us evaluate vulnerability of their ecological roles in nutrient cycling, hydrologic buffering, and providing wildlife forage in northern hemisphere forests. Our results will lay the scientific basis for their use in ecological forecasting of climate change, a tool to provide policy makers with an early warning of biological effects happening on the ground.

**Methods:** In summer 2013, we installed 75 lichen community transects on *Picea mariana* branches in 10 treatment and 2 ambient enclosures (5-7 transects per enclosure) at the SPRUCE experiment. On each branch transect, we estimated the abundance of all lichen species to the nearest 1%. We also installed 320 *Evernia mesomorpha* transplants in these same enclosures (27 per treatment enclosure and 25 per ambient enclosure). The lichen transplants were weighed prior to installation on *P. mariana* branches, providing a benchmark against which we will compare the weights of the same transplants after 1 & 2 (Phase 1) and 5 & 10 year (Phase 2) increments of exposure to climate manipulations.

In fall 2014, we would reread the lichen community transects and reweigh lichen transplants. Meanwhile, we would install 7-10 additional FHM/FIA-style lichen community plots in bogs near enclosures to build a dataset for cross-walking experimental results with regional data. In winter 2014, we would identify lichens collected from this field-work and evaluate data from already-sampled FHM/FIA lichen plots in MN and WI for use in a regional lichen climate index. These data would provide the basis for an analysis focusing on known drivers of lichen community structure with a special emphasis on temperature. This would also provide a context for interpreting changes in response to experimental heat treatments. The regional data will establish regional climate-community associations and aid development of a lichen index for climate.

In fall 2015, we would install 40 FHM/FIA-style lichen plots on a belt transect from southern Illinois to Ontario, passing through Marcell the following summer if the MN and WI FIA lichen data were deemed insufficient. We would repeat lichen community and transplant measurements in the SPRUCE enclosures and incorporate them into the final lichen climate change index.

**Products:**
At least 1 peer-reviewed scientific article
A poster for the FHM Workgroup
Proposal of lichen-based indicators/indices for monitoring climate change in the western Great Lakes region
(d-Schedule of activities):

Year 1 (2014):
1) Revisit SPRUCE experiment, reread lichen community branches and reweigh lichen transplants.
2) Install FIA lichen community plots in the Marcell Exp. Forest, to provide link to regional lichen community gradient model focused on temperature gradient.
3) Based on changes in community and transplant masses and lichen community gradient model, develop initial lichen climate change indicators for selected subset FIA lichen community data
4) Evaluate suitability of existing FIA lichen community data for establishing regional climatic responses of lichen species.
5) Present initial findings at Ecological Society of America meeting in Sacramento, CA in Aug., 2014
6) Present results in a poster for the FHM Workgroup

Year 2 (2015):
1) Revisit SPRUCE experiment, reread lichen community branches and reweigh lichen transplants.
2) Supplemental sampling, as needed, of lichen communities on a belt transect from southern Illinois to Ontario, passing through Marcell Experimental Forest, for a total of 45-50 plots.
3) Analyze regional climatic gradient from existing and supplemental FIA lichen community data.
4) Finalize lichen climate change indicators based on experimental results and selected subset FIA lichen community data and literature.
5) Prepare report and peer-reviewed publication

(e-Relevant citations):


COSTS:

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