Detecting Climate Change in Wetlands in the Adirondack Park: Phase II

EPA Wetlands Program Development Grant CD#96295000
Final Report
March 2017

New York State Adirondack Park Agency
SUNY College of Environmental Science and Forestry Adirondack Ecological Center and Northern Forest Institute
New York Natural Heritage Program
Paul Smith's College Center for Adirondack Biodiversity

Detecting Climate Change in Wetlands in the Adirondack Park: Phase II

Stephen F. Langdon, Gregory J. Edinger, Paul B. Hai, Stacy McNulty, Samuel Beguin, David Patrick, Edward Snizek, Leigh Walrath

A report prepared by:

Adirondack Ecological Center of the SUNY College of Environmental Science and Forestry
Center for Adirondack Biodiversity at Paul Smith's College
New York Natural Heritage Program
New York State Adirondack Park Agency
Northern Forest Institute of the SUNY College of Environmental Science and Forestry

For:
United States Environmental Protection Agency

March 2017

Please cite this report as follows: Langdon, S.F., G.J. Edinger, P.B. Hai, S. McNulty, S. Beguin, D. Patrick (eds.) E. Snizek and L. Walrath. 2017. Detecting Climate Change in Wetlands in the Adirondack Park: Phase II

A report prepared for the U.S. EPA

Photos (clockwise from upper left): Cool air in Glacier Lake St. Agnes Esker Fen, Canada Jay at Bloomingdale Bog, Patterned Peatland in Franklin County, Volunteer training at Paul Smith's College Visitor Interpretive Center.

Unless otherwise noted photos by Stephen Langdon

This report is accompanied by separate Appendices, titled: Detecting Climate Change in Wetlands in the Adirondack Park: Phase II Appendices. 213 pp.

Executive Summary

The New York State Adirondack Park Agency (APA) was awarded Wetland Protection Program Development grant (CD97208000) in 2011: to establish a network of long-term wetland monitoring sites that enable analysis of wetland responses to climate change. The goals of this project were met by identifying wetlands vulnerable to climate change, and developing 1) protocols and criteria for detecting and monitoring climate change effects, 2) data collection training modules for citizen science volunteers, and 3) a web-based GIS database to analyze, interpret, and disseminate information on wetland and watershed condition. In 2014, Phase II of the project (CD 96295000) was funded and began the implementation of the first comprehensive climate change effects detection program for wetlands in the Adirondacks consistent with national climate change detection networks.

This project, titled “Detecting Climate Change in Wetlands in the Adirondack Park: Phase II, ”is the 14th United States Environmental Protection Agency-funded project focused on wetland protection awarded to the APA since 1993, and was the implementation phase of this two-phase project. The two goals of Phase II are to 1) establish baseline conditions of Adirondack peatlands by conducting a wetland condition assessment of 30 sites selected in Phase I and 2) monitor phenological indicators with citizen scientists. To accomplish these goals APA partnered with the New York Natural Heritage Program (NYNHP), the State University of New York College of Environmental Science and Forestry, and Paul Smith’s College. The goals of the project were met on completion of the no-cost extension in 2016. The final products of this project include a network of trained volunteers committed to long-term monitoring of wetlands, a wetland condition database that includes wetland reference condition and phenological data, preliminary data analysis, and dissemination of the data to the public.

Contents

Figures

Tables

Introduction

Wetlands provide important ecosystem services such as flood mitigation, water filtration, recreation and biodiversity that all have great economic, aesthetic and other values to society (Liu et al. 2010, Mitsch and Gosselink 2015). The legal framework for managing wetland impacts that degrade such ecosystem services focuses on local stressors such as unregulated draining, dredging, filling, excavating, etc. (cf. NYS Environmental Conservation Law). While this regulatory focus has offered extremely important protection to wetlands it does not address the suite of stressors from human caused global environmental change such as climate change, atmospheric deposition and invasive species which act at coarser spatio-temporal scales (Vitousek 1994). Because regulatory mechanisms to address these new stressors are currently lacking, it is difficult to adapt management strategies to changing environmental conditions.

In an effort to inform the question of whether there are actions that can be taken to mitigate impacts from climate change, the Adirondack Park Agency, which administers the New York State Freshwater Wetlands Act in the Adirondack Park of New York State, sought to better understand the type, magnitude and direction of changes in wetlands due to climate and other stressors in order to both refine APA management approaches and define sensitivity to stressors. The goal of this effort is to build capacity for adaptive management of Adirondack wetlands and to transfer applicable knowledge to other wetland ecosystems.

Adirondack wetlands have already experienced changing climatic regimes that have altered the phenology of the ecosystem (Beier et al. 2012). These changes will continue to drive changes in wetland structure and function, particularly for the boreal-type wetlands found in the Adirondacks (Jenkins 2010). Climate change effects on a wetland vary depending on a variety of factors related to 1) the nature of the changes in local climate conditions, which may vary regionally (Beier et al. 2011, Raney 2014), 2) the conditions of the local watershed (e.g., the condition of the immediately adjacent uplands), and 3) the vegetation structure and composition and hydrodynamics of the wetland. Local conditions may buffer climate change effects, creating the potential for high-conservation value refugia (Bedford and Godwin 2003, Raney et al. 2013). In addition to negative impacts on wetland functions and biodiversity, climate change will likely alter the carbon source/sink role of wetlands with respect to greenhouse gas balances, potentially leading to greater emissions and creating a positive feedback (Gorham 1991).

A better understanding of how wetland response to climate change is influenced by local conditions will inform optimal management of these important ecosystems at a regional level. This project builds on an earlier effort to determine how to identify, assess, and monitor wetlands that are vulnerable to climate change (Phase I).

Objectives

Our objectives for Phase II were to implement the monitoring framework specifically by 1) capturing reference condition of wetlands determined to be vulnerable to climate change, 2) monitoring phenological conditions of wetlands with citizen scientist volunteers and 3) creating the infrastructure necessary for supporting a monitoring program to extend beyond the project period. What follows is a recapitulation of the climate change vulnerability assessment of Phase

I, an overview of how the objectives of Phase II were met and a discussion of the next steps and potential application of these data.

Study Area

The Adirondack Park of New York State is a 24,000 km^2 area of public and private land protected by New York State regulatory measures that provide a high level of oversight of land-use. The region is characterized by an uplifted dome of Precambrian rock that creates a large extent of elevations much higher than the surrounding St. Lawrence, Lake Champlain, Upper Hudson, Mohawk and Lake Ontario watersheds. The combination of the elevation and the latitude of the Adirondack Park make it a transitional area between northern-temperate and southern boreal biomes which contributes to its high biodiversity and recognition by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as the Champlain-Adirondack Biosphere Reserve. Wetlands in the Adirondacks range in elevation from 30 m to nearly 1600 m.a.s.l. and make up 7 -16 % of major watersheds (Ziemann et al. 2013). There are thousands of lakes and ponds and miles of streams and rivers.

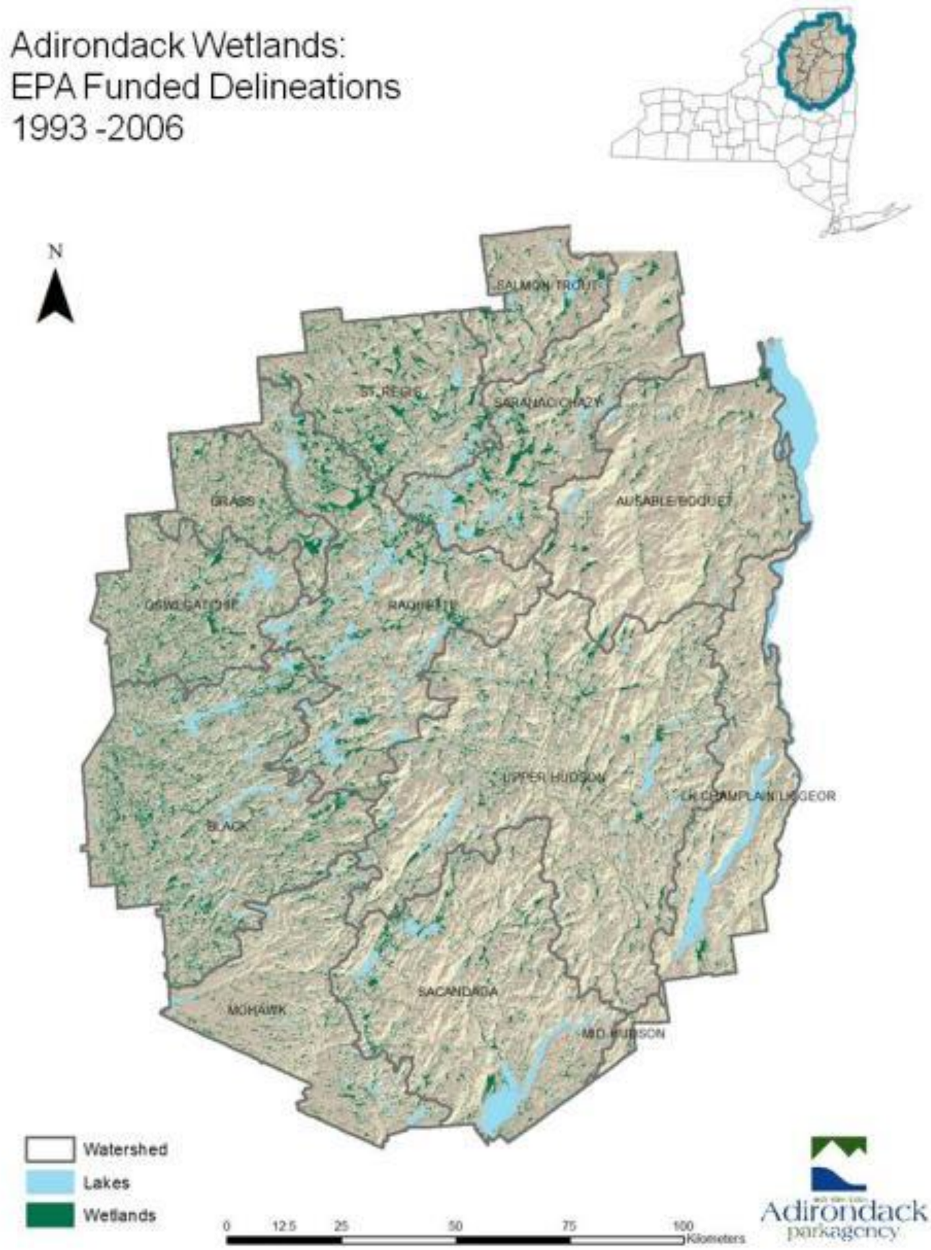

Figure 1: Major watersheds of the Adirondack Park in New York State

Recapitulation of Phase I

As part of Phase I of this project we adapted a climate change vulnerability assessment framework (Glick et al. 2011) to develop a qualitative method to assess wetland vulnerability to climate change. This process is discussed in detail in the Phase I final report but a brief overview is provided here.

Vulnerability under this frame work is defined as a function of three components: Sensitivity, Exposure and Adaptive Capacity, where Sensitivity is the measure of an intrinsic character of a biological system and how that system is likely to be affected by shifting climate regimes. Exposure is the extrinsic nature or degree to which a biological system is exposed to significant climate variations, and Adaptive Capacity is the ability of a system to accommodate or cope with climate change impacts with minimal disruption (Glick et al. 2011). Under this framework wetlands most vulnerable to climate change are those that have greatest Sensitivity, greatest Exposure and the least Adaptive Capacity.

To apply this framework we qualified and quantified the components of vulnerability from Glick et al. (2011) in the following ways. Sensitivity of wetlands was equated to state-wide rarity of wetland ecological communities based on the assumption that rarity of an ecological community reflects that community's capacity to exist under the historic regional climate regimes where it developed. Exposure of wetlands was to be based on the development of historic gridded climate models but subsequent research led us to conclude that the accuracy of such models was not yet sufficient to score Exposure at the appropriate spatial scale. We therefore selected wetland types that captured a range of exposure occurring across the Adirondack region. We found that without sufficient data Adaptive Capacity was difficult to quantify when applied to the biological scale of ecosystems or ecological communities thus we ultimately omitted this aspect of the framework.

To achieve the Phase I objective, we completed a classification crosswalk, reconciling the Cowardin et al. (1979) wetland classification scheme available from jurisdictional wetland maps, with wetland ecological community descriptions from Edinger et al (2014). The classification crosswalk was adapted from previous EPA funded work (NYSAPA 2007) and was applied to all wetland polygons in the Adirondacks, giving each wetland polygon a list of potential ecological community equivalences and their rarity rankings. By selecting the rarest (NYS Heritage Ranking of S3, S2 or S1) ecological communities with the greatest extent (to capture a range of exposure) we concluded that peatlands were among the most vulnerable wetland ecosystems (others are listed in Appendix A of the Phase I final report).

Products of the Phase I Climate Change Vulnerability Assessment include the following items:

1. A GIS containing the crosswalk of ecological community equivalencies to Cowardin Classifications.
2. A cursory assessment of charismatic mega-wetlands of the Ausable and Saranac River watersheds similar to that completed by LaPoint et al. (2004).

Overview of Climate Change Impacts to Peatlands

Peatlands are types of wetlands where hydrologic conditions are such that the rate biomass accumulation exceeds the rate of decomposition resulting in the accumulation of un-decomposed vegetation: peat. Hydrology is controlled primarily by climate but influenced by local geomorphic conditions as well. Peatlands are distributed globally but the vast extent of peatlands occur on the continents of the northern hemisphere where cold temperatures slow decomposition rates. The accumulation of peat since the retreat of the Holocene glaciers (~10,000 years before present in the Adirondacks) has resulted in the global accumulation of nearly 455 x 10^{14} kg or one-third of global soil carbon (Gorham 1991). Thus, at a global scale peatland ecosystems are critical to the carbon cycle because they sequester carbon and are currently functioning as carbon sinks. But because climate warming in northern latitudes can increase peat decomposition rates releasing more atmospheric carbon there is significant concern that peatlands will become a carbon source, creating positive biotic feedback for climate change (i.e., more atmospheric carbon creates warmer temperatures, which releases more carbon from peatlands, which increases atmospheric carbon, which creates warmer temperatures, etc.; cf. Dorropaal et al. 2009).

Peatlands are generally classified along a gradient of pH which is correlative to hydrologic connectivity and nutrient availability. The term 'bog' is commonly used for low-pH, hydrologically isolated, low nutrient-availability peatlands, while the term 'fen' is commonly used for higher-pH, hyrologically connected, high-nutrient availability peatlands. Bogs are notoriously species-poor, but contribute a greatly to β-diversity as the species that grow there are unique, while fens can be extremely species-rich, also with high β-diversity. For example, over 400 species of vascular plants have been recorded in Nelson Swamp, a minerotrophic fen located in central New York State (NYS DEC 2015).

In northern temperate regions like the Adirondacks, peatlands are relatively rare and have high biodiversity conservation value because they are home to species that do not occur in the surrounding landscape (Moore 2002). The primary threat to the biodiversity of northern temperate peatlands is the invasion of woody and vascular plants, which can result in the disruption of plant competitive dynamics by altered temperature, hydrology and nutrient regimes (see, Berg et al. 2009, Eppinga et al. 2009, Hiejmans et al. 2013, Kapfer et al. 2011, Lachance et al. 2005).

Adirondack peatlands are among the largest, southern-most boreal peatlands in eastern North America (Jenkins 2010) positioning these ecosystems at the extremes of their climatic tolerances where potential threats to biodiversity arise from both climate change and by high nitrogen deposition rates (Driscoll et al 2003). Loss of peatland avifauna biodiversity has been documented in the Adirondacks (Glennon 2014, Zuckerberg 2009) though it is not correlated to changes in vegetation. There is a great dearth of information regarding vegetation structure of large Adirondack peatland complexes with no peer-reviewed descriptions thereof (Langdon 2014; but see also Ross et al. 2016). In this context the current effort to develop an Adirondack peatland reference condition database combined with phenological monitoring is critically important for a number of aspects of conservation management and planning of boreal peatlands of the Adirondacks.

I. Objectives

Quality Assurance Program Plan

Following the EPA's guidelines (U.S. E.P.A. 2012) we developed and submitted to EPA a Quality Assurance Program Plan outlining our approach to data collection, analysis and storage. This process was valuable in that it refined our goals and outputs allowing us to improve accuracy, precision, completeness and comparability of our project efforts. Many of the protocols used in the project have been vetted by previous EPA funded projects (e.g., Feldmann et al. 2012).

Objective 1: Wetland Condition Assessment

Methods

A wetlands condition assessment of peatland types determined to be vulnerable to climate change was developed under Phase I of the project. We modeled our wetland condition assessment on the three-tiered wetland condition assessment of EPA (Faber-Langendoen et al. 2012).

Tier I –Landscape condition assessment of our wetland condition assessment included delineation of peatland boundaries, watersheds, physiognomic, phenological, leaf-type, Cowardin classifications and ecological community classification following NYNHP Community Field Form Instructions (Edinger and Hunt1997, Edinger et al. 2014) of targeted wetlands and wetland watersheds. GIS data was processed and developed with ESRI ArcGIS software with ERDAS Stereo Analyst extension on a Plannar heads-up three-dimensional monitor system and an ASUS 3D monitor (see Appendices: protocols are detailed in the Phase I Final Report).

Tier II- Rapid condition assessment of our wetland condition assessment was a site assessment developed by our partner organization the NYNHP. We sampled Tier II metrics in all sites to monitor significant impacts not detected in the Tier 1 assessment. This process provided the opportunity to coarsely ground-truth wetland and watershed vegetation classifications from Tier I.

Tier III- Intensive vegetation assessment. We intensively sampled vegetation following Peet et al. (1998). The methodology is the same used by our partner agency NYNHP and the final data is arrayed as part of the NYNHP Field Form Database. Our criterion for data quality is to have all data collected at this level to be complete, understandable, and transferrable into the metrics used to estimate wetland condition. The sampling method is described in the Phase I final report. In brief, this intensive vegetation survey calls for four 10 m by 10 m subsamples (subplots) within a 20 m by 50 m array (see Peet et al. 1998). Our data quality objective is to have data that will allow us to generate mean and standard deviation estimates for our metrics, based on these subplots.

Objective 1: Outcomes

A. Established a baseline of peatland reference condition and collected novel ecological Information: The Adirondack peatland condition assessment database is arrayed at the NYNHP Field Form database and includes 28 (93% of our goal) complete survey sites and 2 partially complete survey sites. An additional 5 sites were completed under the no cost extension. See the addendum for details. The majority of the field work was completed by professional staff but volunteers came as field assistants and their contribution accounted for 21% of the more than

500 hours of field work. These plots greatly increase the amount of data on the vegetation composition and structure of Adirondack peatlands. This effort has increased the number of surveys and done so with standardized methods; prior to this survey effort there were relatively few vegetation surveys completed in boreal peatlands state wide.

This sampling effort led us to identify a number of interesting and significant ecological community occurrences. Hitchens Pond Bog North is the third known occurrence of a patterned peatland in New York State (Edinger et al. 2014) and apparently the southern-most documented example in the Northeast (see Almquist and Calhoun 2003; Worley 1979). Including this site, we sampled all three currently known occurrences of patterned peatlands in the New York State (Bay Pond Bog, Spring Pond Bog and Hitchens Pond Bog North) with the same methodology, providing an updated baseline for these rare community occurrences.

Figure 2: Spring Pond Bog (top) and Hitchens Pond Bog North (bottom) next to aerial images of those sites showing patterning. Tier III surveys occurred in the three known patterned peatland occurrences in New York State. [Note: scale on aerial images is estimated.]

We identified three old-growth northern white cedar swamp communities in the northern Adirondacks; a rare ecological community with high floristic biodiversity (see Appendix 2; Edinger et al. 2014). We completed Tier III surveys at Chase Fen and Follensby Big Cedar Fen in 2015. The Marcy Swamp peatland complex was surveyed as part of the no-cost extension of this project in 2016. See addendum for details.

Figure 3: Chase fen, a northern white cedar swamp.

B. Technology training in digital photogrammetry: The Tier III wetland condition assessment process has allowed the Adirondack Park Agency to become a leader state-wide in the use and configuration of digital photogrammetry workstations purchased under Phase I and II of this project. Digital photogrammetry workstations have been used by other entities in New York State for years but these systems have been expensive, complex, and built on proprietary technology. The systems used as part of this project are exemplary due to their low cost, use of relatively common desktop hardware, and interface within the familiar ESRI ArcGIS display, analysis, and editing environment common to end-users. The technical expertise developed at the APA has allowed us to provide technical support, trouble-shooting and proof-of-concept to other state agencies including the New York State GIS Program Office, NYS Department of Transportation, NYS Department of Environmental Conservation, NYS Office of Parks, Recreation and Historic Preservation, NYS Public Service Commission, NYS Department of Agriculture and Markets and NYS Information and Technology Services. We have demonstrated the technology and specific applications to numerous local universities, the NYS Department of Environmental Conservation Region 6 Division of Wildlife, The Adirondack Community and Conservation Program of the Wildlife Conservation Society, The Adirondack Chapter of the Nature Conservancy, The U.S. Department of State, Office of International Visitors, International Visitor Leadership Program and others. Additionally this technology has been used for numerous wetland delineations and state land planning as part of APA's regulatory functions. This technology has become incorporated into the daily work-flow of APA wetland scientists.

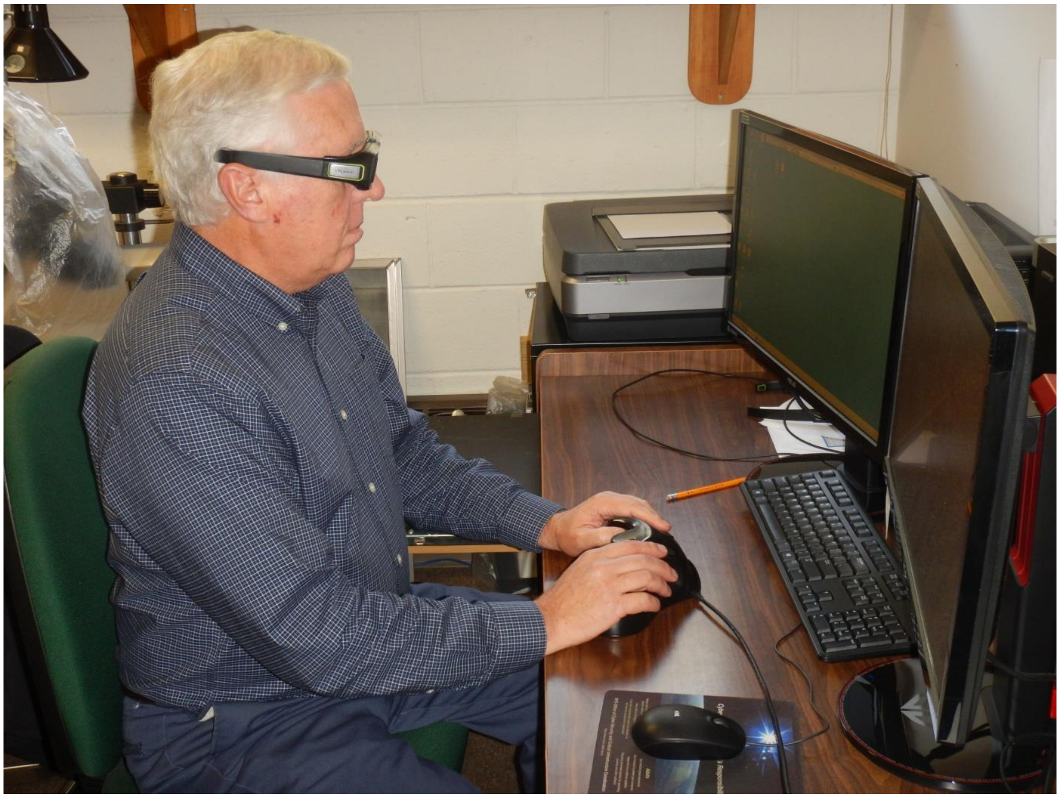

Figure 4: Use of the of digital photogrammetry workstations at the Adirondack Park Agency.

Objective 2: Phenological Monitoring with Citizen Scientist Volunteers

Methods

Phenological assessment of Adirondack wetlands focused on biological and environmental conditions of survey sites. Citizen Scientists with professional staff focused on monitoring phenological indicators of three taxa: birds, amphibians (Anurans) and flowering plants. Professional staff explored the use of data logging environmental monitors (temperature and hydrology monitors) and deployed arrays of data loggers for long-term monitoring.

Citizen Science Training and Monitoring

Biological monitoring was conducted by citizen science volunteers and professional staff who followed well-established protocols to assess three taxa: birds, amphibians and flowering plants. Procedures for the phenological assessment survey were designed to obtain the most reliable data possible from trained volunteers. The protocols themselves are adapted from widely-used and reliable phenological monitoring methods that have been tested by other agencies. Phenological data collection protocols focus on taxa selected for their strengths as climate change indicators and their feasibility for successful incorporation into a citizen science program. Avifauna surveys are adapted from the National Park Service (Fancy and Sauer 2000). They are designed to quantify detection probability and allow for comparison of relative abundance among species, habitats or areas. They also detect trends in population size for selected boreal peatland species as well as several upland forest species. Amphibian surveys are adapted from USGS's North American Amphibian Monitoring Program (2015) and are designed to quantify presence and absence. Flowering plant surveys were adapted from USA National Phenology Network protocols (USA NPN) and focus on abundant wetland flora. Phenological assessment protocols can be found in Developing a monitoring framework for detecting wetland response to climate change in the Adirondack Park: Phase I, Appendix D.

Citizen scientist volunteer outreach began in Phase I with a web presence and content development (Figure 5 a and b) hosted by SUNY ESF and Paul Smith's College.

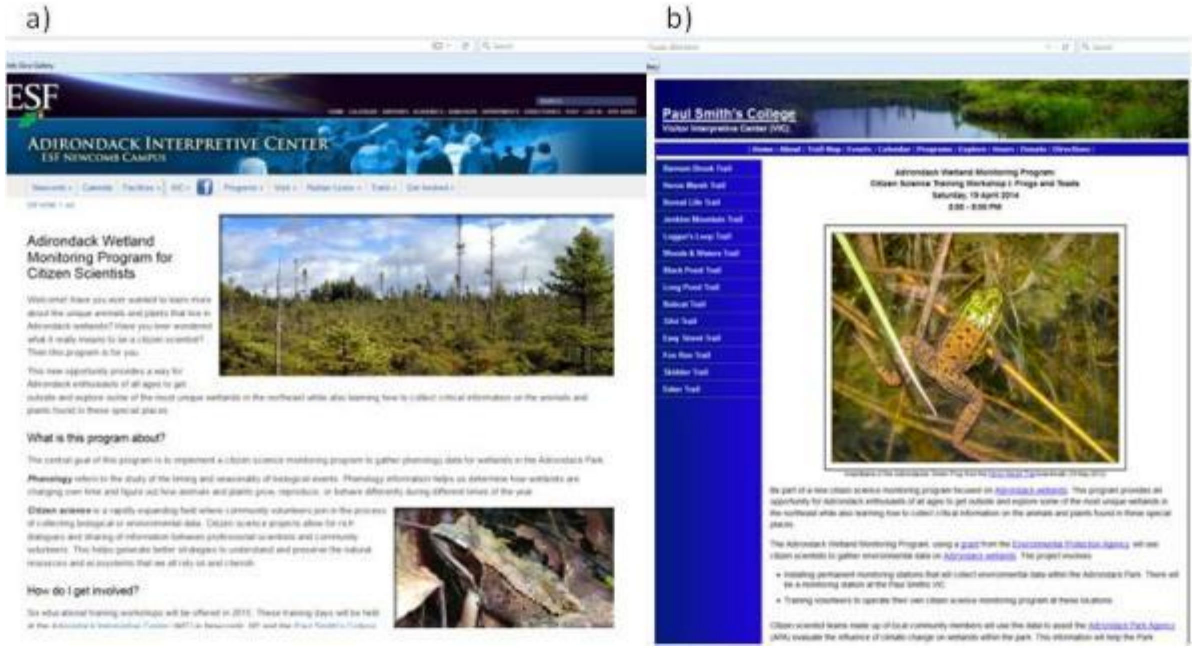

Figure 5: Screen shots of websites posted during the extent of the project a) SUNY ESF Adirondack Interpretive Center and b) volunteer training announcement hosted by our partner organization Paul Smith's College Visitor's Interpretive Center.

Citizen scientist volunteer trainings were held at two locations, the Paul Smith's College Visitor's Interpretive Center and the Adirondack Visitor's Interpretive Center in Newcomb. Collectively, there were a total of 129 attendees (some were repeat attendees) dedicating over 700 hours to training (Table 1). Training sessions focused on identification of target taxa but also included an introduction to the project, an overview of wetland and peatland values and ecology, review of field methods and practice of field protocols. Informal bog walks which provided the opportunity to engage with volunteers in the field and broaden their experience were held in the summer of 2014. Additional trainings were conducted as part of the no-cost extension in 2016, See the no-cost extension addendum for details.

Table 1: Citizen Science volunteer training sessions Phase II, 2014 and 2015.

Date	Location	Duration	Topic	Attendees	Total Volunteer hours
Saturday, April 19, 2014	Paul Smith's	3	Amphibians	11	33
Saturday, April 19, 2014	Newcomb	3	Amphibians	12	36
Saturday, May 17, 2014	Paul Smith's	3	Birds and Flowers	15	45
Saturday, May 17, 2014	Newcomb	3	Birds and Flowers	10	30
Summer 2014	Various Sites	16	Bog Walks (protocols, review of taxa)	10	160
Saturday, February 28, 2015	Paul Smith's	3	All Taxa, survey methods	7	21
Saturday, February 28, 2015	Newcomb	3	All Taxa, survey methods	9	27
Saturday, March 21, 2015	Paul Smith's	3	All Taxa, survey methods	6	18
Saturday, March 21, 2015	Newcomb	3	All Taxa, survey methods	9	27
Saturday, May 30, 2015	Newcomb	8	Survey Methods, Data Collection App.	10	80
Saturday, May 30, 2015	Paul Smith's	8	Survey Methods, Data Collection App.	30	240
Total		**56**		**129**	**717**

Phenological data collection began in the summer of 2015. The citizen science data infrastructure developed under Phase I includes 1) cloud-hosted PostgreSQL/PostGIS spatial database backend, 2) a mobile/tablet/desktop application (app) for data entry and 3) a public-facing website where these data can be viewed in tabular and map formats.

We used a subscription product, Fulcrum (http://www.fulcrumapp.com/) as the backend platform for development of this interface. Fulcrum provides native applications (apps) for Apple and Android that allow multiple users to enter data while in the field, with or without an internet connection, or at the desk using a browser interface. A custom form was created for this project that enabled citizen scientists and project staff to enter phenological observation data into the Fulcrum database (Figure 6).

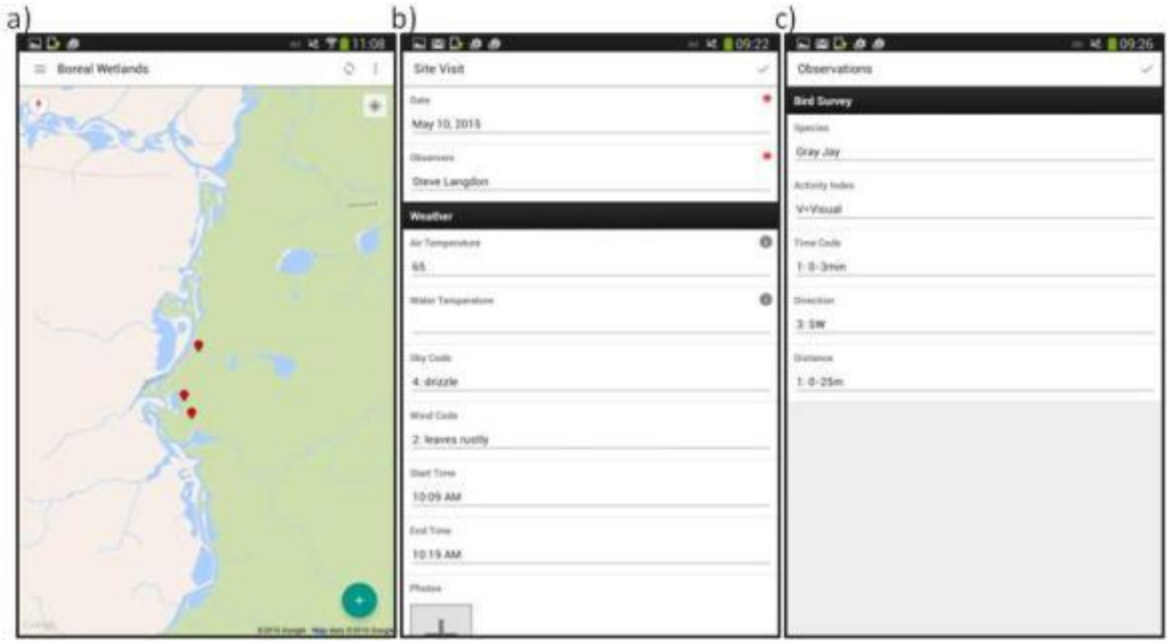

Figure 6: Screen shots of the custom form (Fulcrumapp) designed for the phenological monitoring program showing a) interactive map that helps volunteers navigate to observation points, b) a form for recording environmental conditions and c) attributes of each observation recorded for a bird point count.

Fulcrum stores data in an online (PostgreSQL/PostGIS) database and provides an API that enables users to access data in a number of formats, including csv, xlsx, kml or json. Our partner organization (SUNY-ESF) provided the academic license for this service at no cost to the project.

The public webpage (url: http://adirondackatlas.org/boreal_wetlands/) leverages popular Javascript libraries such as Bootstrap.js and Leaflet.js that add responsiveness and map interactivity (Figure 7a and b). Data is pulled live from the Fulcrum API into the website, so newly collected data is visible on the public page as soon as it is synced with the Fulcrum database. Site functionality includes type-ahead search, zoom map to feature, pop-ups with drill-down tables to facilitate data exploration and an embedded data entry interface allowing registered users to connect to Fulcrum and enter data.

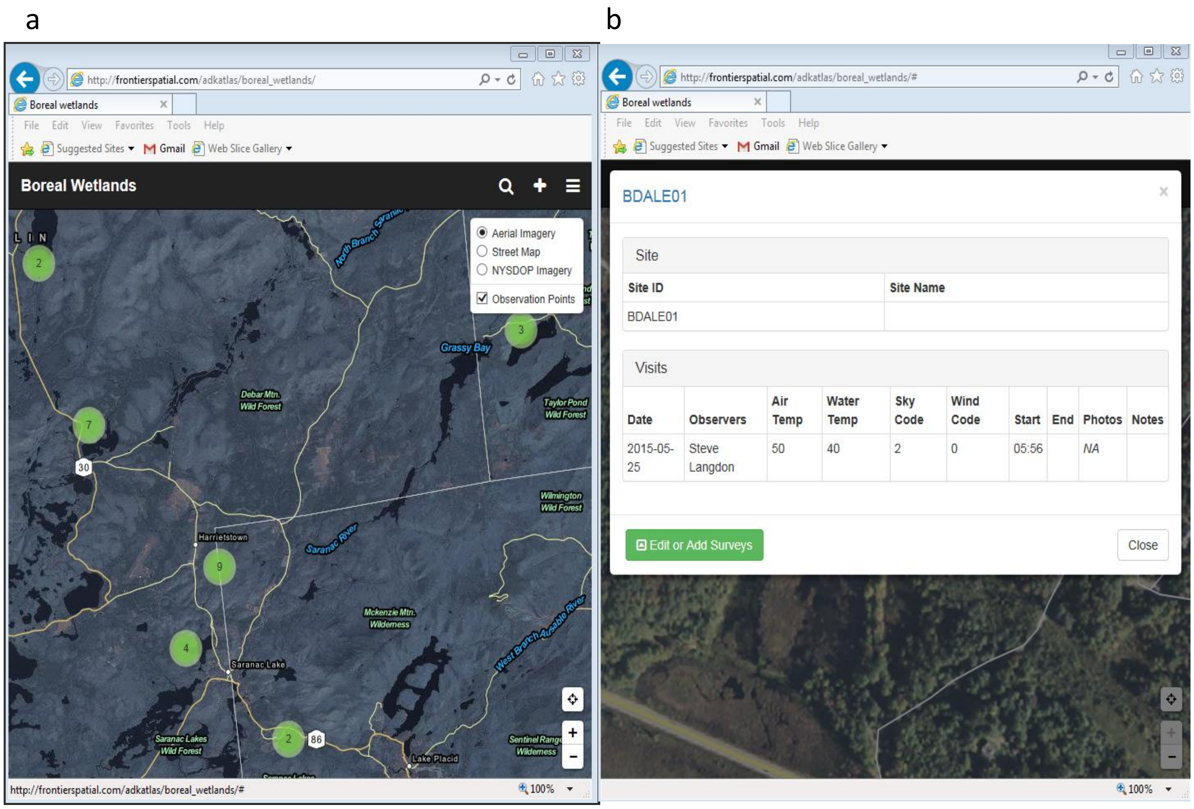

Figure 7: The boreal wetlands website showing a) initial view of survey sites in the northern Adirondacks and b) observation information displayed when clicking on each survey site.

Results and Discussion

A total of 129 phenological surveys were completed by professional staff and volunteers in 2015. The majority of these were bird surveys (53% of total), followed by plant surveys (30%) and herpeto-fauna surveys (17%). We believe the interests of the volunteers and the short seasonal window for herpeto-fauna surveys were responsible for the low herpeto-fauna survey rate. Data are arrayed at the website: http://adirondackatlas.org/boreal_wetlands/. Additional phenological surveys were completed as part of the no-cost extension of the project in 2016 (see the no-cost extension addendum for details).

Our bird survey protocol was based on a widely used methodology and because of this, the app has been tested by NYS DEC Region 6 Division of Fish and Wildlife and the Wildlife Conservation Society field crews. Both organizations have boreal bird monitoring expertise; a peripheral outcome is that the citizen scientist app may allow these crews to shift from paper field forms in the future, broadening the influence of this project.

While we are pleased with the accomplishments and hard work of volunteers and staff, we fell short of expectations for 2015. We found high participation of volunteers in field trainings and relatively low participation in the field monitoring. Most field data was entered by professional staff who completed the majority of the phenological observations. There are a number of reasons for low volunteer participation in field monitoring. First, the launch of the citizen science data interface (a deliverable from Phase I of the project) was delayed until spring 2015, thus volunteers had only one season to be trained on and become familiar with the data interface. Professional staff provided volunteers the opportunity to use paper data forms and entered paper data via the constructed app. We found a great technological divide among volunteers with many people not embracing smart phone technology but very eager to do the observations.

As a result, we requested and completed a no-cost extension to run the volunteer program through 2016 in which we addressed the participation issues by focusing trainings later in the spring, having participants download the app beforehand and make a field coordinator available to citizen scientists for phenological monitoring trips, similar to the bog walks done in 2014 (see the no-cost extension addendum for details).

We learned some key lessons from survey forms provided to citizen scientists at various training sessions that will improve future citizen science participation. These include the following points:

- The volunteers wanted their site assignments as soon as possible and providing that information and linkage may help ensure higher survey follow-through.
- Increase field trainings rather than focus on winter classroom trainings. This allows volunteers to get outside with the expert birders/scientists as much as possible and increases volunteer confidence. Likewise, spending as much time as possible on the app to make volunteers more comfortable with its use is important.
- There was continuity in the training schedule and building on prior knowledge: the winter indoor trainings coupled well with the spring outdoor practice sessions.
- Email updates keep people in the loop and provide feedback and project progress, along with a few fun species facts.
- The field equipment (e.g., notebooks, hand-lenses) was greatly appreciated by volunteers because it provided a token demonstration of the value of their efforts.

Sharing information about the project on social media and local media increases visibility and disseminates ecological information about peatlands, climate science etc.

Monitoring Environmental Conditions

We tested a number of methods for monitoring important environmental conditions that are important climate change indicators. Cold air, the duration of snow pack and water budget are all important factors in the ecology of peatlands (e.g., Crum 1988, Curtis 1959, Heijmans 2013). Because these factors are closely correlated with climate they are important indicators of climate change (EPA 2014).

Figure 8: Temperature data logger array.

To measure snow pack and the influence of cold air on our target sites, we deployed temperature data logger arrays at five pilot sites (three plot sites at Glacial Lake St. Agnes and one site each at Silver Lake Bog and Paul Smith's College Visitor Interpretive Center) at the beginning of the project. Each data logger array consisted of two temperature data loggers (Hobo Pendant 64k, Onset Computer Corp.) powered by CR-2032 Lithium batteries randomly located in un-forested peatland sites and mounted on a 2.0 m long, 5 mm diameter fiberglass poles driven ~1 m into the peat (total price per unit is ~$150; Figure 9). Two data logging temperature sensor arrays were deployed at Paul Smith's Visitor's Interpretive Center pilot site, four arrays were deployed at open bogs within the Glacial Lake St. Agnes Peatland Complex at Shingle Shanty Preserve and Research Station and one array was deployed at Silver Lake Bog. All arrays were located randomly and out of sight of any public trail or access point to minimize disturbance to the equipment. Temperature data loggers for the initial deployment during Phase I were provided by Shingle Shanty Preserve and Research Station. Data loggers for the ongoing deployment were purchased under Phase II.

In 2014 the Paul Smith's VIC, Silver Lake Bog, and Glacial Lake St. Agnes sites were selected to monitor hydrology. The reduced number of hydrologic monitoring sites was necessitated by some or all of the following: 1) the relatively high per site cost of equipment (total of $1,040 per site), 2) the proximity of each site to an existing weather station (sites needed to be within 20 km of each site to limit the cost per site to just over $1,040), 3) an evaluation of the potential for vandalism, and 4) the ease of access over the 5-10 year service life of the equipment.

At each selected site a single Hobo U20 water level meter and rain gauge (Paul Smith's VIC and Silver Lake Bog only) were installed in 2014. In addition to the monitoring equipment, at each site a 1.5 inch diameter x 48 inch deep well (PVC pipe covered with a well-screen) was constructed to house the Hobo U20.

Results and Discussion

Results of the pilot study to measure duration of frost period data are shown in Figure 10. The three pilot sites located in the Glacial Lake St. Agnes Peatland Complex (GLSA01- 03) are within 1 km of each other in northern Hamilton County, Silver Lake Bog (SLB01) is in western Clinton County and Paul Smith's College Visitor Interpretive Center (PSC01) is in southern

Franklin County. The duration of the frost free period at these sites ranges from less than 3 weeks to more than 3 months. The factors that are related to this variation are elevation, topography and stochasticity of weather conditions. The limited data suggests a negative linear relationship between elevation and duration of frost free period ($p = 0.049$) and a positive linear relationship to watershed area ($p=0.003$; Table 2). The authors acknowledge that these preliminary data are too limited to make conclusions about which of the above factors plays the most important role. To increase the sample size and compare a broad range of landscape characteristics captured in the Tier I Landscape Condition Assessment we have deployed temperature data logger arrays at 11 additional survey sites across the Adirondacks (Figure 11). These data logger arrays were retrieved, serviced, and redeployed in September 2016 by partner organizations.

Due to technical difficulties with supporting barometric monitoring equipment the monitoring of the hydrologic data failed to provide meaningful data in 2015. The equipment was serviced and redeployed in the fall of 2016. The results of the data collection effort are reported on in the no-cost extension addendum. Continued long-term deployment of both the temperature and hydrological loggers is necessary to understand the results of this data in the context of current and future microsite environmental conditions.

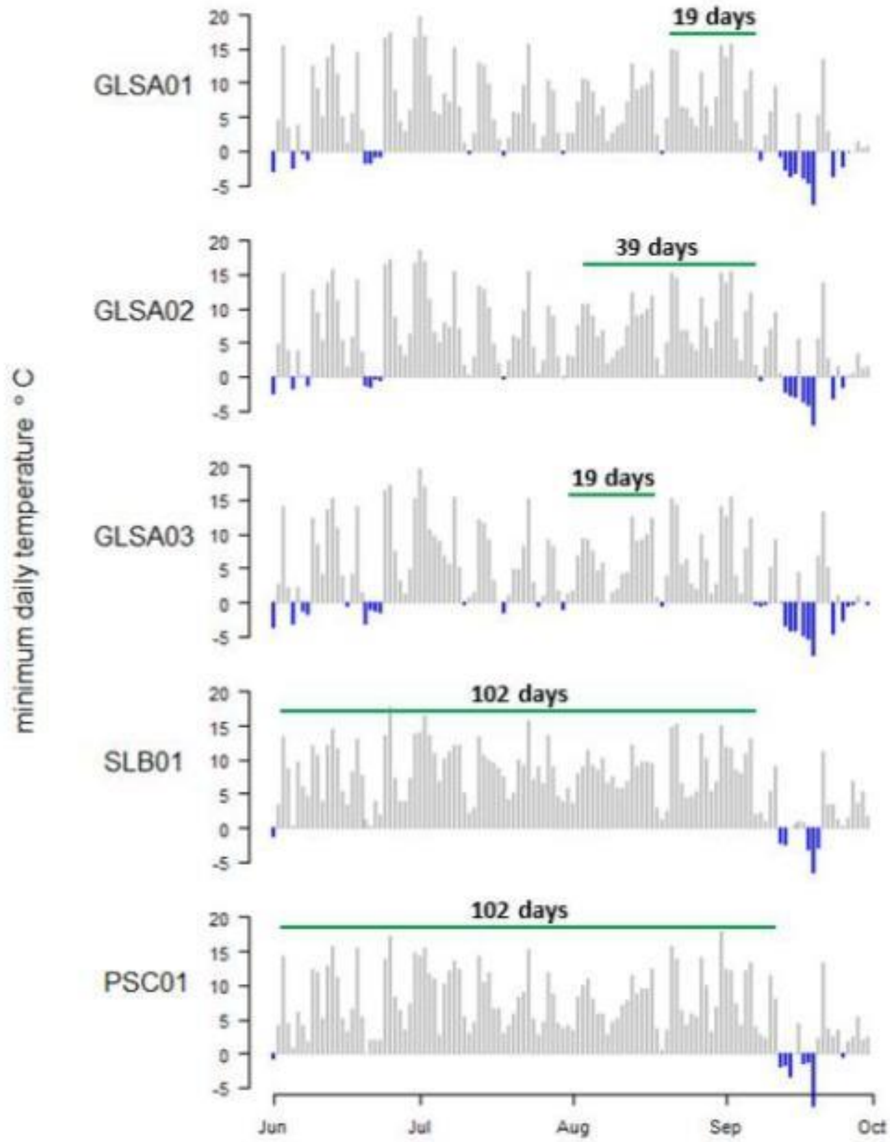

Figure 9: Temperature Data Loggers - duration of the frost free periods. Summer months of 2015 at five pilot sites across the Adirondacks, Glacial Lake St. Agnes (GLSA) (three sites), Silver Lake Bog (SLB) and Paul Smith's College Visitor Interpretive Center (PSC). The frost free period is the longest period (days) of the entire year where the temperature did not fall below 0° C.

Table 2: Site characteristics for environmental measurements at three peatlands in Adirondack Park, New York.

Site Name	Site Label	County	Elevation (m)	Watershed Size (ha)	Frost-free Days
Glacial Lake St. Agnes Peatland Complex	GLSA01-03	Hamilton	534	117	19-39
Silver Lake Bog	SLB01	Clinton	455	4807	102
Paul Smith's College Visitor Interpretive Center	PSC01	Franklin	499	580	102

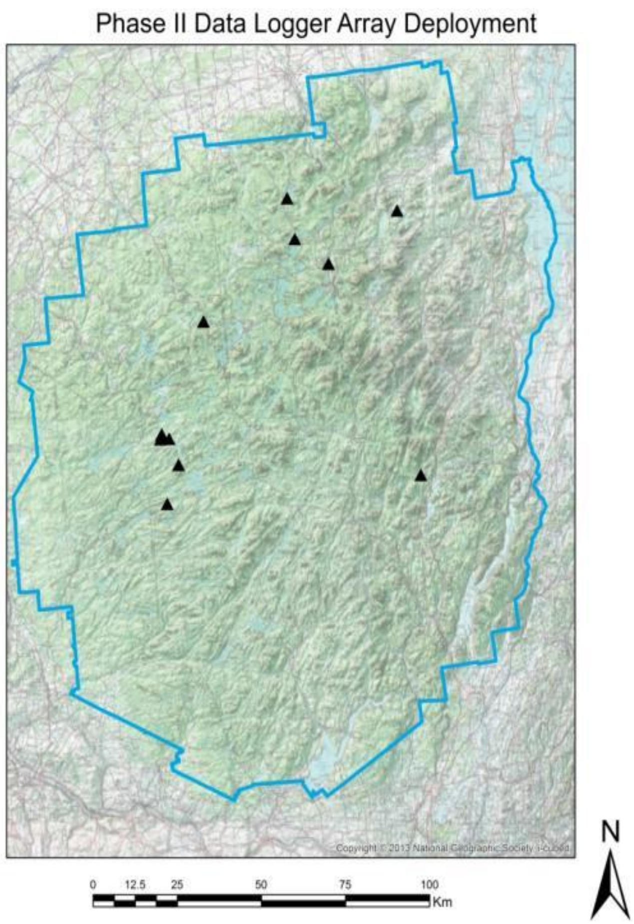

Figure 10: Deployment of temperature data logger arrays at survey sites 2014-2015. Data loggers were deployed in summer 2015 and were serviced and redeployed by project partners in fall, 2016.

Objective 3: Citizen Science Infrastructure

The third objective of this project was to develop a methodology and data management infrastructure meaningful to long-term monitoring of vulnerable wetlands. We developed a data collection and curation infrastructure for wetland plant community and phenology data that can stand on its own beyond the period of the grant. Wetland condition assessment data are arrayed in the NYNHP database and phenological monitoring data are arrayed in the compatible database created under this project at SUNY ESF. This data infrastructure is fully operational and will support continued phenological monitoring and future statistical analysis.

a) b)

Figure 11: a) Volunteer training at the Adirondack Interpretive Center in Newcomb, NY and b) entering phenological observation data on a tablet computer with the Citizen Science Data Interface.

Further, we recruited, trained and deployed a network of almost 30 dedicated volunteers capable of long-term monitoring of wetland phenology with a system of quality control in place within the citizen science data interface app (Figure 12). The citizen science program was extended with no additional costs through the 2016 season. Please see the no-cost extension addendum for details.

Conclusions and Next Steps

Citizen Science Monitoring Program

Management of the citizen science phenological monitoring is through our partner organizations at SUNY ESF, the Adirondack Ecological Center and Northern Forest Institute. An account of the 2016 no-cost extension and improvements in citizen scientist participation is provided in the addendum to this report.

Transfer of protocols

To broaden the impact of this project, we explored the suitability of protocols developed here to be used by other agencies and regions. We provided technical support and proof of concept in the configuration of digital photogrammetry workstations and have presented the application of our climate change vulnerability assessment of wetlands at the 2015 Society for Wetland Scientists conference.

Data Analyses and Publications

We chose to use methodologies for wetland condition assessments that were well established and vetted by our partner agency, the NYNHP, because doing so maximizes the utility and efficacy of these data. As mentioned above, we have increased the amount of peatland ecological community data in the Adirondacks using a method that is standardized. These data create the capacity to compare our vegetation structure and composition of peatland communities statewide providing a number of opportunities for research into better understanding climate change impacts. These opportunities include:

1. A description and comparison of structural and compositional characteristics of northern white cedar fens in the Adirondacks and New York State. Chase Fen, Big Cedar Fen, Silver Lake Bog and the Marcy Swamp peatland complex provide examples of this ecological community type with circumneutral pH which may stand out from the far richer Nelson Swamp (see Anderson and Leopold 2002, Forrester et al. 2005, Scanga 2010) as acidic northern white cedar swamp (cf. Sperduto and Kimball 2011).
2. A description and comparison of landscape, structural and compositional characteristics of patterned peatlands in New York State. We have sampled the two known occurrences of this ecological community (Bay Pond Bog and Spring Pond Bog) and identified a third (Hitchens Pond Bog North). Brandreth South Fen has similar diversity and composition yet morphological features of a patterned peatland are not as apparent here. Almquist and Calhoun (2003) describe a southern outlier patterned peatland that may provide a useful comparison.
3. An analysis of Tier I, Tier II and Tier III scores with diversity indices and floristic quality assessment (FQA) score (similar to Feldmann et al. 2012) would provide an interesting benchmark for testing predictability of wetland condition in the relatively pristine sites assessed during this project.
4. An analysis of the relationship of environmental conditions (i.e., temperature and hydrologic monitoring data) and landscape conditions, upon the collection of the data logger arrays in fall 2016. These data may help us better understand the role of cold air in the vegetation structure of peatlands and how these relate to watershed characteristics. What role does watershed shape, size, and elevation play in the controlling air temperatures in peatlands across the Adirondacks? These data are pertinent to discussions about how local topography can buffer the effects of climate change and inform the prediction of species refugia (e.g., Hiejmans et al. 2013, Bedford and Godwin 2003).

References

Almquist, H., and Calhoun, A. J. K. 2003. A coastal, southern-outlier patterned fen: lily fen, swans island, Maine. Northeastern Naturalist, 10(2), 119–130. http://doi.org/10.1656/1092-6194(2003)010[0119:ACSPFL]2.0.CO;2

Anderson, K. L., and Leopold, D. J. 2002. The Role of Canopy Gaps in Maintaining Vascular Plant Diversity at a Forested Wetland in New York State. Journal of the Torrey Botanical Society, 129(3), 238–250. http://doi.org/10.2307/3088774

Bedford, B. L., and Godwin, K. S. 2003. Fens of the United States: Distribution, characteristics, and scientific connection versus legal isolation. Wetlands, 23(3), 608–629. http://doi.org/10.1672/0277-5212(2003)023[0608:FOTUSD]2.0.CO;2

Beier C.M., Signell S.A., Luttman A., DeGaetano A. 2011. High-resolution climate change mapping using gridded historical climate products. Landscape Ecology 27(3): 327-342.

Beier, C. M., Stella, J. C., Dovčiak, M., and McNulty, S. A. 2012. Local climatic drivers of changes in phenology at a boreal-temperate ecotone in eastern North America. Climatic Change, 115(2), 399–417. http://doi.org/10.1007/s10584-012-0455-z

Berg, E., Hillman, K.M, Dial, R., and DeRuwe, A. 2009. Recent woody invasions of wetlands on the Kenai Peninsula lowlands, south-central Alaska: A major regime shift after 18,000 years of wet Sphagnum-sedge peat recruitment. Can. J. Forest Res. 39: 2033-2046. doi:10.1139/X09-121

Cowardin, L. M., Carter. V., Golet, F.C., LaRoe, E.T. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Washington D.C.

Crum, H. 1988. A Focus on Peatlands and Peat Mosses. University of Michigan Press, Ann Arbor, MI. 306 pp.

Curtis, J. 1959. Vegetation of Wisonsin; an ordination of plant communities. University of Wisconsin Press, Madison, WI. 640 pp.

Dorrepaal, E., Toet, S., van Logtestijn, R. S. P., Swart, E., van de Weg, M. J., Callaghan, T. V., and Aerts, R. 2009. Carbon respiration from subsurface peat accelerated by climate warming in the subarctic. Nature, 460(7255), 616–619. http://doi.org/10.1038/nature08216

Driscoll, C. T., Whitall, D., Aber, J., Boyer, E., Castro, M., Cronan, C., Goodale, C., Groffman, P., Hopkinson, C., Lambert, K., Lawrence, G., and Ollinger, S. 2003. Nitrogen pollution in the northeastern United States: Sources, effects, and management options. BioScience, 53(4): 357–374. doi:10.1641/0006-3568(2003)053[0357:NPITNU]2.0.CO;2.

Edinger, G.J., and Hunt, D. 1997. Community Field Form Instructions: Site Survey Summary and Community Forms 1, 2, 3. NYNHP Latham NY. 25 pp. and Appendices.

Edinger, G.J., Evans, D.J., Gebauer, S., Howard, T.G., Hunt, D.M., and Olivero, A.M. (eds). 2014. Ecological Communities of New York State. Second Edition. A revised and expanded edition of Carol Reschke's Ecological Communities of New York State. New York Natural Heritage Program, New York State Department of Environmental Conservation, Albany, NY.

Eppinga, M. B., Rietkerk, M., Wassen, M. J., and Ruiter, P. C. D. 2009. Linking habitat modification to catastrophic shifts and vegetation patterns in bogs. Plant Ecol. 200(1): 53–68. doi:10.1007/s11258-007-9309-6.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012. Assessment of wetland ecosystem condition across landscape regions: A multimetric approach. Part B. Ecological Integrity Assessment protocols for rapid field methods (L2). EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Fancy, S.G., and Sauer, J.R. 2000. Recommended methods for inventorying and monitoring landbirds in national parks. USGS/BRD Patuxent Wildlife Research Center. 13 pp.

Feldmann, A.L., Howard, T.G., and Spencer, E.A. 2012. Pilot wetland condition assessment of palustrine emergent marsh in the Upper Hudson River watershed. A report prepared for the NYSDEC Division of Water by the New York Natural Heritage Program. Albany, NY.

Forrester, J. A., Yorks, T. E., and Leopold, D. J. 2005. Arboreal vegetation, coarse woody debris, and disturbance history of mature and old-growth stands in a coniferous forested wetland. The Journal of the Torrey Botanical Society, 132(2), 252–261. http://doi.org/10.3159/1095-5674(2005)132[252:AVCWDA]2.0.CO;2

Glennon, M. J. 2014. Dynamics of boreal birds at the edge of their range in the Adirondack Park, NY. Northeast. Nat. 21(1): 51-71. doi:10.1656/045.021.0121.

Glick, P., Stein, B.A., and Edelson, N.A. 2011. *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment.* National Wildlife Federation, Washington D.C.

Gorham, E. 1991. Northern Peatlands: Role in the Carbon Cycle and Probable Responses to Climatic Warming. Ecological Applications, 1(2), 182–195. http://doi.org/10.2307/1941811

Heijmans, M. M. P. D., van der Knaap, Y. A. M., Holmgren, M., and Limpens, J. 2013. Persistent versus transient tree encroachment of temperate peat bogs: effects of climate warming and drought events. Global Change Biology, 19(7), 2240–2250. http://doi.org/10.1111/gcb.12202

Jenkins, J. 2010 *Climate Change in the Adirondacks: The Path to Sustainability*. Comstock Publishing, Ithaca, New York. 183 pps.

Kapfer, J., Grytnes, J.-A., Gunnarsson, U., and Birks, H. J. B. 2011. Fine-scale changes in vegetation composition in a boreal mire over 50 years. J. Ecol. 99(5): 1179–1189. doi:10.1111/j.1365-2745.2011.01847.x.

Lachance, D., Lavoie, C., and Derochers, A. 2005. The impact of peatland afforestation on plant and bird diversity in southeastern Quebec. Ecoscience. 12: 161-171. doi:10.2980/i1195-6860-12-2-161.1.

Langdon, S.F. 2014. Vegetation composition and structure of a large boreal peatland complex in the Adirondacks of New York State. M.S. Thesis. SUNY College of Environmental Science and Forestry. Available from: http://pqdtopen.proquest.com/doc/1668381791.html?FMT=ABS

Lapoint, S., Curran, R., Halasz, S., Barge, J., Spada, D., and Karasin, L. 2004. Wetlands Effects Database and GIS for the Adirondack Park. U.S. EPA State Wetlands Protection Program Report. 26 pp.

Liu, S., Costanza, R., Troy, A., D'Aagostino, J., and Mates, W. 2010. Valuing New Jersey's Ecosystem Services and Natural Capital: A Spatially Explicit Benefit Transfer Approach. Environmental Management, 45(6), 1271–1285. http://doi.org/10.1007/s00267-010-9483-5

Mitsch, W.J. and Gosselink, J.G. 2015 Wetlands, 5th Edition. John Wiley and Sons, Inc. New York, NY. 456 pp

Moore, P. D. 2002. The future of cool temperate bogs. Environ.Conserv. 29: 3–20. doi:10.1017/S0376892902000024.

North American Amphibian Monitoring Program - Patuxent Wildlife Research Center. (n.d.). Retrieved November 30, 2015, from https://www.pwrc.usgs.gov/naamp/

NYS Adirondack Park Agency. 2007. Ausable/Boquet NYNHP to NWI Crosswalk: First Approximation and Revisions. Technical Document.

NYS Dept. of Environmental Conservation (NYSDEC). Nelson Swamp Unique Area - (n.d.). Retrieved November 23, 2015, from http://www.dec.ny.gov/lands/8150.html

NYS Environmental Conservation Law, Article 24, Freshwater Wetlands Act - wetart24b.pdf. (n.d.). Retrieved November 18, 2015, from http://www.dec.ny.gov/docs/wildlife_pdf/wetart24b.pdf

Peet, R. K., Wentworth, T. R., and White, P. S. 1998. A Flexible, Multipurpose Method for Recording Vegetation Composition and Structure. Castanea, 63(3), 262–274.

Raney, P. A., Fridley, J. D., & Leopold, D. J. (2013). Characterizing Microclimate and Plant Community Variation in Wetlands. Wetlands, 34(1), 43–53. http://doi.org/10.1007/s13157-013-0481-2

Ross, A. M., Johnson, G., and Gibbs, J. P. (2016). Spruce grouse decline in maturing lowland boreal forests of New York. Forest Ecology and Management, 359, 118–125. http://doi.org/10.1016/j.foreco.2015.09.039

Scanga, S. E., and Leopold, D. J. 2010. Population vigor of a rare, wetland, understory herb in relation to light and hydrology. The Journal of the Torrey Botanical Society, 137(2–3), 297–311. http://doi.org/10.3159/09-RA-047R1.1

Sperduto, D., and Kimball, B. 2011. The nature of New Hampshire: Natural communities of the granite state. Durham, N.H: New Hampshire.

USA National Phenology Network | USA National Phenology Network. (n.d.). Retrieved November 30, 2015, from https://www.usanpn.org/

U.S. Environmental Protection Agency. 2012. EPA requirements for Quality Assurance Project Plans. EPA QA/R-5. Accessed: 12/7/11 from: http://www.epa.gov/quality/qs-docs/r5-final.pdf

U.S. Environmental Protection Agency. 2014. Climate change indicators in the United States, 2014. Third edition. EPA 430-R-14-004. Accessed 8/20/15 from: www.epa.gov/climatechange/indicators.

Vitousek, P. M. 1994. Beyond Global Warming: Ecology and Global Change. Ecology, 75(7), 1861–1876. http://doi.org/10.2307/1941591

Worley, I. 1979. Address to the Adirondack Nature Conservancy. Unpublished Report, NYS Adirondack Park Agency.

Ziemann, A.C., Reagan, K.D., Colarusso, T.W., Allen, A.B., Spada, D., Barge J., Rooks, M.W., and Boguki, D.J. 2013. Effects of and Enhancements to the New York State Adirondack Park Agency's Wetland Protection Program. U.S. EPA Wetland Protection Program Report. 179 pp.

Zuckerberg, B., Woods, A. M., and Porter, W. F. 2009. Poleward shifts in breeding bird distributions in New York State. Glob. Change Biol. 15(8): 1866–1883. doi:10.1111/j.1365-2486.2009.01878.x.