**CNH Lakes Year 1 Report**

**December 5, 2016**

**Accomplishments**

**What are the major goals of the project?**

The overarching goals of this project with respect to intellectual merit are to:

1. Understand how land-use change (e.g., from forest to developed) and agricultural land-management decisions alter nutrient fluxes through lake ecosystems;
2. Represent the consequences of those nutrient fluxes as changes in lake water quality metrics that are meaningful to people;
3. Determine how those water quality metrics feed back into human decision making by altering property values and by motivating the formation and activities of self-organized citizen groups;
4. Scale our results and understanding of three focal lake catchments to a diverse set of lake catchments representative of continental-scale gradients.

In terms of broader impacts, the project seeks to:

1. Engage citizen groups surrounding three focal lake catchments and use our research and modeling to support science-based monitoring, advocacy, and volunteerism;
2. Provide integrative, interdisciplinary graduate education that will build human capital for the next generation of coupled natural-human researchers focused on freshwater issues.

**What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

All-hands CNH project personnel Year 1 workshop:

* The workshop was a platform for team building across disciplines and institutions. Project participants worked toward building a common conceptual foundation to support the coupling of disciplinary models, to characterize and prioritize products for the project, and to develop a strategic plan for how to use the coupled models in Year 2 to address the project’s research questions.
* All project personnel were trained in the conceptual underpinnings of all of the disciplinary models being used in the project (including a land-use decision making model, agronomy model, hydrological model, limnological model, hedonic property value model, and social science model).
* We hosted Maude LaMarche from University of Wisconsin-Extension at the project’s Year 1 workshop in Mountain Lake, VA. Maude interacted with the project team, including graduate students; presented information about Wisconsin lake associations (and similar organizations); and discussed the UW Extension database of lake association history and activities.
* Graduate students and postdoctoral research associates from different disciplines and institutions received interdisciplinary training on coupled human-natural systems.

Penn State University modeling workshops:

* Two workshops were hosted at Penn State University (April 2016 and September 2016) to couple the hydrological and limnological models in the project (PIHM and GLM, led by co-PIs Duffy and Carey); and the economic land-management and agronomic models (SDP and Cycles, let by PI Cobourn and co-PI Kemanian).

Engaging our lake association partners:

* Sorice (co-PI) made a field site visit to Oneida Lake (Bridgeport, NY), where he was hosted by Lars Rudstam (collaborator) at the Cornell Biological Field Station. Sorice and Rudstam met with biologists and lake association leaders to discuss the project, get feedback, and explore data sources. (September 2016)
* Sorice made a field site visit to Lake Mendota (Madison, WI), where he was hosted by Hanson (co-PI), and his lab (including Dugan, postdoc, and Hart, Ph.D. student). Sorice and Hanson met with the Clean Lakes Alliance to discuss the project, get feedback, and explore data sources. (October 2016)
* Sorice made a field site visit to Lake Sunapee (Sunapee, NH), where he was hosted by Weathers (co-PI). Sorice met with the Lake Sunapee Protective Association to discuss the project, get feedback, and explore data sources. (November 2016)
* Co-PI Carey, co-PI Weathers, and Ph.D. student Ward organized a workshop at the Lake Sunapee Protective Association in August 2016 to present initial findings from the Sunapee lake water quality modeling effort and explore data sources.

Creating relationships with new lake association partners

* Cobourn (PI), Carey (co-PI), Hanson (co-PI), and Sorice (co-PI) established a relationship with Eric Olson, University of Wisconsin Extension Lakes and met to discuss knowledge, exchange of database of lake associations (and similar organizations), and needs associated with lake associations around Lake Mendota and across the state. (February 2016)

Postdoc and graduate student literature review paper

* The postdocs and graduate students supported by the project are collaboratively developing a review of the coupled natural-human systems literature that focuses on freshwater lake catchments. Weathers (co-PI) is facilitating the interaction between graduate students in different disciplines and institutions, and the students are learning new approaches to model coupling and integration that will be directly applied to this project.

Project management and outreach

* We established and built out the project’s wiki-based task management system for the Lake Mendota modeling work, project administration (e.g., all minutes from the monthly group teleconferences), and manuscript development/tracking (<http://www.organicdatascience.org/cnh>). The site also serves as an interface with the public by providing open access to information about our activities, models, and team members.
* We set up and have begun populating the project website ([www.cnhlakes.frec.vt.edu)](http://www.cnhlakes.frec.vt.edu)) and twitter account (@CNHLakes).
* An undergraduate student intern worked with Cobourn (PI), Carey (co-PI), and Boyle (co-PI) to develop a video introduction to the project in the style of a whiteboard video (<https://www.youtube.com/watch?v=NYAkCpTziCM>). The video was used to introduce the Lake Sunapee Protective Association (LSPA) to the project.
* The team collaboratively developed a project authorship policy that delineates how project manuscripts will be handled, which is available on the organic data science website.

Specific Objectives:

Build the foundations for the Lake Mendota coupled natural-human systems model

* We compiled and archived driver datasets (e.g., climate, catchment boundaries, weir operations) to be used in common across social and natural models. All datasets are archived and publicly available at <http://cnhlakes.limnology.wisc.edu>, our data website maintained by our North Temperate Lakes LTER partners at the University of Wisconsin.
* We coupled the hydrological (PIHM) and limnological (GLM) models for Lake Mendota, and calibrated the models to reflect observed conditions from 1979-2013.
* We fully coupled the agronomic (Cycles) and hydrologic (PIHM) models.
* We developed a workflow to couple the economic land-management model with agronomic (Cycles) model by developing yield and nutrient leaching functions based on soils, weather, and agricultural production practices in the watershed.
* We began developing and extracting from the limnologic model key water quality metrics to be used in economic hedonic analysis.
* We obtained property sales data from two sources for our three focal catchments and cleaned the data for the hedonic analysis.

Extend LAGOS database for scaling up and extrapolation

* Soranno (co-PI) Michigan State University is working with Stachelek (Ph.D. student) to expand the LAGOS database to include a larger set of lake catchments for scaling up and extrapolation.

Significant Results:

A key objective of our project is to identify the lake water quality metrics influenced by human behavior (e.g., through land-use and land management) and to which humans respond, via changes in property values and collective action undertaken by citizen groups. In Year 1, we identified critical water quality metrics that form the foundation for our set of essential management variables (EMVs). EMVs drive the coupling between human and natural components of the system, and thus influence system dynamics over space and time. Specifically, we found that oxygen concentration is a key indicator and driver of water quality in lakes. Decreases in oxygen concentration lead to altered ecosystem function as well as harmful consequences for aquatic biota, such as fishes. This is a novel contribution to the literature, because little is known about how the oxic environment of bottom waters, especially the timing and magnitude of anoxia in eutrophic lakes, responds to changes in human behavior. Understanding how important ecosystem states, such as hypolimnetic anoxia, may respond to differing climatic conditions and human decisions requires a model that couples physical-biological conditions and sufficiently captures the thermal stratification that leads to strong oxygen gradients.

To this end, we used a lake ecosystem model that is at the center of our CNH project to analyze the effects of changes in important meteorological drivers (air temperature, wind speed, and relative humidity) on hypolimnetic anoxia in Lake Mendota, a eutrophic, north temperate lake. We used the anoxic factor as an index to capture both the temporal and spatial extent of anoxia. Air temperature and relative humidity were found to have a positive correlation with anoxic factor, while wind speed had a negative correlation. Air temperature was found to have the greatest potential impact of the three drivers on the anoxic factor, followed by wind speed and then relative humidity. Across climatic conditions, variation in the simulated anoxic factor was primarily due to changes in the timing of onset and decay of stratification. Given the potential for future changes in climatic conditions, especially increases in air temperature, this study (Snortheim et al., 2017) provides important insight into how these changes will alter lake water quality and other ecosystem services. Work in Year 2 will leverage these results to couple the lake water quality, property value, and social science models, and to extrapolate to a set of similar lake catchments spanning the northcentral and northeastern US.

Key outcomes or other achievements:

Coupling the hydrologic (PIHM) and agronomic models merged the hydrological cycle and the energy balance of both models while fully retaining the biogeochemistry in Cycles. PIHM is used to simulate the water table depth (recharge and lateral flow) and infiltration. These fluxes are used as boundary conditions to simulate water redistribution, evaporation and transpiration in the soil column in each grid cell. The water redistribution uses the algorithm developed for Flux-PIHM. The same model is also used to simulate soil temperature. Therefore, lateral water flow now transports solutes through the grid and river network. The model combination is tentatively called C-PIHM and is currently hosted in Kemanian’s (co-PI) GitHub account.

**What opportunities for training and professional development has the project provided?**

The project has supported so far 16 new personnel, including 3 undergraduate interns, 8 graduate students, 3 postdocs, and 2 research associates/technicians.

Through the Year 1 workshop and two Penn State modeling workshops, the project has created an opportunity for graduate students to gain exposure to a wide range of process-based modeling approaches that are not available in their home department/institution. Graduate students are collaborating on multidisciplinary elements of the project and developing disciplinary and interdisciplinary journal articles under the guidance of faculty mentors. They are also being mentored on the process of working in a multidisciplinary team environment, and the project has provided new training on how economists, hydrologists, soil scientists, and social scientists study lake catchments and human decision-making.

As part of the two workshops at Penn State (described above under “Major Activities”) senior investigators, graduate students, and postdocs learned new techniques in lake-catchment modeling, data analysis, and visualization (April 2016 and November 2016). The workshops’ focus was on training in the implementation and operation of the Penn State Integrated Hydrologic Model (PIHM) and General Lake Model (GLM), using R and GIS software resources necessary to set up, execute, analyze, and visualize the models’ outputs.

Graduate students and research technicians have learned new skills in database synthesis and management; programming and data analytics (in R); developing geospatial data and visualizations for the study sites and reformatting the data to make it easily accessible for all investigators; and coupling, calibrating, and improving the computational efficiency of process-based models.

The GLEON 18 Training Workshop in July 2016, “Doing the most with your data: processing, products, metadata and web applications,” organized by co-PI Hanson and postdoc Dugan, helped scientists of all career stages in the Global Lake Ecological Observatory Network (GLEON) learn how to use the tools needed to access and use data relevant to ecological analysis and modeling. The objectives of the workshop were to: use R to download data from the LTER data repository, the CUAHSI data center, and the GLEON DataONE member node; learn the basics of metadata; use the R package EML to develop metadata formatted in the Ecological Metadata Language; upload data and metadata to the GLEON DataONE member node (demonstration only, due to current log-in changes in Data ONE); aggregate data the easy way using dplyr and tidyr; become familiar with R package Lake Metabolizer, which contains a variety of methods for calculating lake metabolism from buoy data; and build a Shiny App. Shiny is a web application framework for R, which you can use to turn your R code into an interactive application.

One undergraduate communications intern was supported at Virginia Tech (spring 2016); two undergraduate interns were supported at the Cornell Biological Field Station (summer 2016).

**How have the results been disseminated to communities of interest?**

A description of the project, its objectives, and results to date have been presented to our lake association partners. At three separate meetings with the Lake Sunapee Protective Association (LSPA), the overall project was described by Weathers (co-PI), Carey (co-PI), Ward (Ph.D. student), and Sorice (co-PI), and the team has engaged with the LSPA staff, board, and volunteers. Those meetings include: 1) the LSPA annual meeting (July 2016), where Weathers described the project; 2) a water quality research meeting where Carey, Ward, and Weathers described the overall project, showed the project introduction video, and discussed the limnologic modeling efforts (August 2016); and 3) an exploratory meeting with Sorice, Weathers, and members of the LSPA community to discuss the history, volunteerism, and success of LSPA in accomplishing their mission (November 2016). In addition, results were disseminated to the Oneida Lake Association (OLA) and New York Department of Environmental Conservation by Rudstam (senior personnel) and Hetherington (postdoc). The overall project was presented in poster format at the 60-year anniversary celebration for the Cornell Biological Field Station (June 2016).

**Products**

**Within the Products section, you can list any products resulting from your project during the specified reporting period, such as:**

Note: the superscript G indicates graduate student and P indicates postdoc in the products listed below. Project personnel are highlighted in bold.

Journals:

SnortheimG, C.A., **P.C. Hanson**, K.D. McMahon, J.S. Read, **C.C. Carey**, and **H.A. Dugan**. In press. Meteorological drivers of hypolimnetic anoxia in a eutrophic, north temperate lake. *Ecological Modelling*. DOI: 10.1016/j.ecolmodel.2016.10.014

**HetheringtonP, A.L**., A.S. Zhao, J.M. Hunn, R.L. Schneider, **C.C. Carey**, and **L.G. Rudstam**. Comparison of clearance rates of zebra (*Dreissena polymorpha*) and quagga (*Dreissena rostriformis bugensis*) mussels across a wide range of lake temperatures. In review at *Aquatic Ecology*.

DoubekG, J.P., M. LavenderG, A.K. WinegardnerG, M. BeaulieuG, P.T. KellyG, **C.C. Carey**, A.I. Pollard, D. Straile, and J.D. Stockwell.Increased reservoir discharge is related to decreased zooplankton density across the continental United States. In review at *Freshwater Science.*

Read E.K., L. Carr, L. De Cicco, **H.A. DuganP**, **P.C. Hanson**, J.A. HartG, J. Kreft, J.S. Read, L.A. Winslow. Water quality data for national-scale limnological research. In review at *Water Resources Research*.

Books: n/a

Book Chapters: n/a

Thesis/Dissertations:

DodsonG, Laura. 2016. “Statistical Relationships Between Observational Water Quality and Catchment Agricultural Intensity in Rural Maine.” M.S., Agricultural and Applied Economics, Virginia Tech.

Conference Papers and Presentations:

**HetheringtonP, A.L.**, **C.C. Carey**, **K.M. Cobourn**, R.J. Figueiredo, and **P.C. Hanson**. 2016. [Modeling effects of human decision-making on lakes in coupled human natural systems](http://www.organicdatascience.org/cnh/images/7/7b/FINAL_GLEON_18_Poster_Hetherington_06242016.pdf). Poster presented at the Global Lake Ecological Observatory Network (GLEON) 18 All-Hands and NETLAKE Meetings, 4-8 July 2016, Lunz and Gaming, Austria.

**Carey, C.C**., **A.L. HetheringtonP**, R. Figueiredo, and **P.C. Hanson**. GRAPLE: GLEON research and PRAGMA lake expedition. Oral presentation at the Global Lake Ecological Observatory Network (GLEON) 18 All-Hands and NETLAKE Meetings, 4-8 July 2016, Lunz and Gaming, Austria.

**Rudstam, L.G**. Ecological forecasting – the art of predicting the future in an era of global change – examples from Oneida Lake, New York. Kaunas, Lithuania, October 2016.

**Rudstam, L.G**. 60 years on Oneida Lake. Department of Natural Resources seminar series, September 2016.

Other Publications: n/a

Technologies or Techniques: n/a

Patents: n/a

Inventions: n/a

Licenses: n/a

Websites:

<http://cnhlakes.limnology.wisc.edu>; a website that provides metadata and datasets needed by team members.

<http://www.cnhlakes.frec.vt.edu>; a website that provides information to the public about the project.

<https://www.organicdatascience.org/cnh>; a semantic wiki-based website that provides a public interface for the project, as well as a task-based project management system.

Other Products:

We have developed a spatial data set of single family residential real estate sales in the communities with frontage on the three study lakes (Mendota, Oneida and Sunapee). We have begun to merge this with limnological and landscape data for Lake Mendota to support estimation of the first hedonic model.

We created and archived a database on <http://cnhlakes.limnology.wisc.edu> to provide hourly resolution NLDAS climate data, water level data, and water quality observational datasets for the three focal catchments.

We developed an online, queryable repository of model parameters for different lakes at <https://drive.google.com/drive/u/1/folders/0ByXbKrEldcVnYjFpZEZXUzlZTDg>

Rudstam, L. G. 2016. Web Data on Knowledge Network for Biocomplexity. Zooplankton survey of Oneida Lake, New York, 1964 to present ([https://knb.ecoinformatics.org//#view/kgordon.17.65](https://knb.ecoinformatics.org/#view/kgordon.17.65)); phytoplankton survey of Oneida Lake, New York, 1975-present ([https://knb.ecoinformatics.org//#view/kgordon.31.73](https://knb.ecoinformatics.org/#view/kgordon.31.73)); limnological data and depth profile from Oneida Lake, New York, 1975-present (<http://knb.ecoinformatics.org/#view/kgordon.35.70>).

**Participants**

There are no limits on the number of participants you list for this section; however, you must list participants who have worked one person month or more for the project reporting period. You have the option of selecting “nothing to report” in this section. For Research Experience for Undergraduates (REU) sites and supplements, specific questions will be listed in this section.

**What individuals have worked on the project?**

|  |  |  |
| --- | --- | --- |
| Name | Most Senior Project Role | Nearest Person Month Worked |
| Griffin Adams | Undergraduate Intern | 1.5 |
| Kevin Boyle | Co-PI | 1.0 |
| Cayelan Carey | Co-PI | 3.0 |
| Kelly Cobourn | PI | 3.0 |
| Laura Dodson | M.S. student | 0.5 |
| Christopher Duffy | Co-PI | 1.0 |
| Hilary Dugan | Postdoc | 1.0 |
| Paul Hanson | Co-PI | 1.0 |
| Julia Hart | Ph.D. student | 2.0 |
| Amy Hetherington | Postdoc | 8.0 |
| Armen Kemanian | Co-PI | 1.0 |
| Stephanie Roh | Undergraduate Intern | 3.0 |
| Rachel Rozum | M.S. student | 0.05 |
| Yuning Shi | Postdoc | 0.75 |
| Lele Shu | Ph.D. student | 1.0 |
| Patricia Soranno | Co-PI | 1.0 |
| Michael Sorice | Co-PI | 1.0 |
| Joseph Stachelek | Ph.D. student | 1.0 |
| Bethel Steele | Research Technician | 2.0 |
| Susan Tan | Undergraduate Intern | 3.0 |
| Nicole Ward | Ph.D. student | 3.0 |
| Kathleen Weathers | Co-PI | 2.0 |
| Weizhe Weng | Ph.D. student | 1.0 |
| Charlie White | Research Associate | .025 |
| Yu Zhang | Ph.D. student | 2.0 |

**What other organizations have been involved as partners?**

The online service will as you for additional information such as: type of partner organization, name, location, partner’s contribution to the project.

* Academic center; Virginia Center for Housing Research; Blacksburg, VA; provided property sales data to support estimation of hedonic model.
* Distributed organization; Pacific Rim Application and Grid Middleware Assembly (PRAGMA); online; provided computing support for simulation scenarios.
* Distributed organization; Environmental Data Initiative (EDI); online; provided data curation and archiving consultation.
* Lake association (not-for-profit); Lake Sunapee Protective Association (LSPA); Sunapee, NH; provided information about the history and mission of the lake association and access to archived lake association documents.
* Lake association (not-for-profit); Oneida Lake Association (OLA); Syracuse, NY; provided information about the history and mission of the lake association and published request for historical documentation from members in newsletter.
* Lake association (not-for-profit); Clean Lakes Alliance (CLA); Madison, WI; provided information about the history and mission of the lake association and access to archived lake association documents.
* Academic; University of Wisconsin Extension Lakes; Stevens Point, WI; provided information about lake associations and similar organizations across the state and access to a database of lake association information and activities.
* Research (not-for-profit); Cary Institute of Ecosystem Studies; Millbrook, NY; provided support for Weathers (co-PI) and Steele (research technician).
* Academic; Cornell Biological Field Station; Shackelton Point, NY; provided support for Rudstam (senior personnel), 2 research technicians, and 2 undergraduate student interns.

**Have other collaborators or contacts been involved?**

* Andrew McCoy, Director, Virginia Center for Housing Research
* Corinna Gries, Information Manager, North Temperate Lakes Long-term Ecological Research (NTL LTER) site, University of Wisconsin Center for Limnology
* James Jackson, Cornell Biological Field Station fish connection and Oneida Lake Association connection for Oneida Lake
* James Watkins, Cornell Biological Field Station, advice on mussel experiments
* Alexander Karatayev, Buffalo State, advice on mussel experiments
* Xuifeng Zhang, Jinan University, mussel filtration experiments
* Xueying Mei, Anhui Agricultural University, mussel filtration experiments
* Matt Hipsey, University of Western Australia, GLM
* Eric Olson, University of Wisconsin Extension Lakes
* Maude LaMarche, University of Wisconsin Extension Lakes
* Renato Figueiredo, University of Florida

**Impacts**

You have the option of selecting “nothing to report” in this section.

**What is the impact on the development of the principal discipline(s) of the project?**

The project’s principal disciplines are: economics, agronomy/soil science, hydrology, limnology, and social science. Disciplinary impacts to date are as follows:

* Agronomy/soil science. The C-PIHM model opens up new opportunities for tracking water and nutrients in agricultural watersheds. To the best of our knowledge, no model has accomplished a full coupling of the water and nitrogen cycling while routing water through the landscape. This project provides a perfect platform for the application of this model and its further expansion (e.g. P cycling modeling, in-stream processes, and coupling with CLM-Lakes).
* Hydrology. We are working in coupling the research models from three science disciplines: catchment hydrologic science, agricultural soil science and lake aquatic ecology in this aspect of the project. The development of shared research resources such as models, data analytic and visualization tools is a major component of this work.
* Limnology. We are experiencing a change in our approach to synthesis in aquatic ecology, one that is based on disparate data sources used to answer questions that span ecosystem boundaries and broad geographic gradients. This project is developing the models, data sets, and workflows needed to answer questions that cross traditional boundaries of ecosystems, disciplines, and institutions. The resources created herein, and the capacity developed, are already being re-used by collaborators in other projects, including NSF-supported INSPIRE (Hanson and Dugan), the North Temperate Lakes LTER (Hanson), and the Pacific Rim Applications Grid Middleware Assembly (PRAGMA, Hanson and Carey).

**What is the impact on other disciplines?**

n/a

**What is the impact on the development of human resources?**

The project is training 16 new personnel in the science of coupled natural-human systems and building the human capital necessary to study freshwater systems from a multidisciplinary perspective. In addition, the project is exposing established professionals from disparate disciplines to concepts and modeling techniques from other disciplines, bridging the disciplinary gaps needed to understand coupled natural-human system dynamics across time and space. Hiring efforts across institutions include advertising to and recruiting a diverse pool of candidates.

**What is the impact on the institutional resources that form infrastructure?**

n/a

**What is the impact on the information resources that form infrastructure?**

We have developed a number of data products that facilitate the analysis of coupled natural-human systems in three focal lake catchments and across a continental gradient (via the expansion of the LAGOS database). In a parallel project we are continuing to develop collaboration software to be used in this effort (Organic Data Science, NSF INSPIRE project) for lake-catchment scientists which includes automated workflows that documents and registers data sources and model results for lake-catchment modeling anywhere in the US.

**What is the impact on technology transfer?**

n/a

**What is the impact on society beyond science and technology?**

n/a

**Changes/Problems**

If not previously reported in writing to the agency through other mechanisms, provide the following additional information or state, “nothing to report”, if applicable.

**Changes in approach and reason for change:** n/a

**Actual or anticipated problems or delays and actions or plans to resolve them:**

A postdoctoral research associate recruited for the project (Amy Hetherington) is on leave for a family emergency; we are currently reorganizing tasks to cover her absence. Salary savings from her position will be used to partially fund a postdoc in freshwater ecology and a research technician in economics/computer programming.

**Changes that have a significant impact on expenditures:** n/a

**Significant changes in use or care of human subjects:** n/a

**Significant changes in use or care of vertebrate animals:** n/a

**Significant changes in use or care of biohazards:** n/a