Annual Report for the NSF-sponsored Ecological Forecasting Initiative Research Coordination Network

February 1, 2021

This is a condensed and updated report from our annual report to the National Science Foundation in December 2020.

The overarching goal of the project is to create a community of practice that builds capacity for ecological forecasting by leveraging NEON data products. Through meetings, working groups, and collaborative code development we aim to achieve the following objectives:

Objective 1. Define community standards and best practices for developing, sharing, and archiving forecasts and models

Objective 2. Increase the number and diversity of NEON-enabled forecasts by developing and hosting the NEON Ecological Forecasting Challenge

Objective 3. Create educational materials to empower scientists at all career stages to forecast using NEON data products

Objective 4. Support the creation of software to produce NEON-enabled forecasts at intensive and collaborative coding-focused workshops

Objective 5. Align forecast outputs and decision support with the needs of forecast users at mission-driven agencies to guide decision making, and

Objective 6. Synthesize forecasts to examine how limits to forecastability vary across ecological systems and scales.

Major Activities

Due to COVID-19 restrictions on travel, all major activities of the Ecological Forecasting Initiative Research Coordination Network (EFI-RCN) occurred through virtual meetings. Over the year, we effectively organized the community through multiple means that include large virtual meetings, smaller virtual working groups, collaborative software development, and sessions at society meetings.

Our first major activity during the first year of the EFI-RCN was running a virtual workshop May 12-13, 2020 that included over 200 attendees (https://ecoforecast.org/efi-rcn-2020-conference/). The objectives of the workshop were to 1) give an introduction of the EFI-RCN, 2) provide an overview of the "supply side" of NEON data products available for use in ecological forecasting, 3) discuss the "demand side" of ecological forecasting and how organizations can use ecological forecasts, and 4) discuss topics and needs for an ecological forecast challenge (similar to a data science competition) to bring the community together collaboratively to create forecasts using NEON data products. We finished the meeting by working together to brainstorm cyberinfrastructure, educational, and software needs to empower individuals and groups to participate in an ecological forecasting challenge using NEON data.

Our second major activity was the launch of the NEON Ecological Forecasting Challenge (https://ecoforecast.org/efi-rcn-forecast-challenges/). The NEON Ecological Forecasting Challenge is similar to a data science challenge or model-intercomparison project except that this is a true forecast -- the validation data hasn't been collected yet at the time predictions are made. The primary goals of this challenge are to improve our predictive capacity for five research areas, all of which have both scientific and societal value, to advance the discipline of ecological forecasting, and to build community. Across these five forecast areas we are excited to learn more about the patterns of predictability of different ecological processes and what modeling frameworks, mechanistic processes, and statistical approaches best capture community, population, and ecosystem dynamics. We have designed the Challenge to encourage a collegial, supportive environment focused on friendly competition and participation across a range of disciplines (hydrologists, epidemiologists, data scientists, statisticians, computer scientists, etc.) not just ecologists.

The five theme areas the Challenge spans aquatic and terrestrial systems, and population, community, and ecosystem processes across a broad range of ecoregions that uses data collected by NEON. The design of the Challenge is the result of contributions from the May 2020 virtual EFI-RCN meeting, including partner organizations and staff from NEON and post-meeting work by Design Teams to develop the protocols for each of the themes. The five design teams of ~10 experts in the particular theme were led by early career scientists (graduates and post-docs). The result of the Challenge design was a website that describes the rules for submitting and the methods used to process NEON data. We have "officially" launched the challenge through an AGU Townhall session, emails to the EFI List and colleagues, a press release by Virginia Tech that was also posted on NEON's blog, short videos produced by NEON

that highlight the five different themes, and twitter. We have 30 teams signed up for the challenge and five undergraduate and graduate classes that are using the Challenge in their instruction this upcoming spring semester.

Our third major activity was organizing ecological forecasting sessions, symposia, and town hall meetings at major society meetings. We sponsored an oral session at the Ecological Society of America (ESA) meeting that highlighted a range of ecological forecasting projects. We sponsored a symposium at the Ecological Society of America meeting that provided an introduction and discussion about the Ecological Forecasting Initiative, including talks on ecological forecasting theory, the NEON Ecological Forecasting Challenge, ecological forecasting education, and forecast co-development with stakeholders. At the American Geophysical Union meeting we supported a session on ecological forecasting that included a talk from the winner of the ESA Ecological Forecasting Prize and a Townhall session that provided an introduction to the NEON Ecological Forecasting Challenge along with talks from leads of the EFI working groups. We also organized an ecological forecasting session at the Association for the Sciences of Limnology and Oceanography that was canceled due to COVID19.

Our fourth major activity was general community building activities that included the maintenance of a website, working group meetings, regular newsletters, regular blog posts, and an active twitter feed. The Ecological Forecasting Initiative's Cyberinfrastructure, Methods & Tools, EFI Student Association, Education, Diversity, Equity, and Inclusion, Social Science, and Partners & Knowledge Transfer working groups, Forecast Challenge design meetings for the five Challenge themes, and three book groups (two related to diversity, equity, and inclusion, and one book about spatio-temporal statistics in R had over 200 Zoom calls during the first year of the project. Progress by the working groups and design teams were shared in four blog posts on the ecoforecast.org website and through six newsletters that were sent to a listserv with 698 members. Finally, our twitter feed (@eco4cast) has over 1,200 followers with 67 tweets and 348 mentions during the first year of the project.

Our fifth major activity focused on efforts targeted towards educational materials and activities to promote and increase diversity, equity and inclusion. Efforts included compiling over 100 educational resources related to topics and processes in ecological forecasting. These materials range from online tutorials, videos related to specific forecasting topics, online books and courses, etc. This set of resources provides us with a baseline to identify gaps where additional resources for specific tools or topics need to be developed, which will be the focus of year 2 of the RCN. In addition, we are drafting a 1-page brief to share with guidance counselors and academic advisors about recommended courses to help students prepare for ecological forecasting. The diversity, equity, and inclusion activities include a book club to discuss topics related to racial and social equity. A group met in the summer to discuss The Years That Matter Most: How College Makes or Breaks Us by Paul Tough and another group met in December 2020 and January 2021 to read Caste: The Origins of Our Discontents by Isabel Wilkerson. We have a four part virtual seminar series titled "Conversation on Diversity and Data". The first

panel was held on November 19 with 3 panelists who talked about their experience at MSIs with what diverse students need to thrive in data- and computer-heavy settings. The second panel about culturally competent data science training was held on January 20 and we have additional panels scheduled for February and March to discuss how four-year data-driven programs can support students transferring from community college and what kind of online tools are useful and work well for remote learning.

Key outcomes or Other achievements

Our May 2020 workshop replaced a three day in-person workshop that was scheduled at the same time, but that was canceled due to COVID-19. Shifting to a virtual format allowed us to increase our participation and diversity. We were originally space-limited to 65 in-person participants (the original site was NEON headquarters in Boulder, CO), but with our virtual meeting, we had 205 people register to access the workshop materials, with 150 individuals consistently joining on Day 1 and 110 individuals who consistently participated on Day 2. We welcomed participants from around the globe, with almost 10% of participants calling in from outside the U.S. Moreover, instead of being limited to 15 graduate student participants, we ended up with over 50 graduate and undergraduate students who participated in the meeting. In association with the larger meeting, we hosted a 1-day meeting for graduate students in the RCN where they online the mission and goals of the [EFI Graduate Student Association](). Finally, the virtual meeting was formally evaluated by a staff member at NEON. The report from the evaluation will help guide the future activities of the network.

Although the transition from an in-person to a virtual workshop was daunting, comments from the post-workshop survey indicated that it was highly appreciated by the community and having the virtual workshop was key to getting community feedback and ideas and creating the design teams that made it possible to launch the NEON Ecological Forecast Challenge 7 months after the workshop. We have shared our lessons learned from hosting the virtual workshop in a [blog post](https://) which was converted and accepted for publication in the [Bulletin of the Ecological Society of America](). Our lessons learned were also included with the experiences from five other conferences that went virtual this year for a manuscript submitted to the Limnology and Oceanography Bulletin.

Key outcomes associated with the specific objectives include:

Objective 1.
We successfully developed a white paper defining standards for saving forecast output and generating metadata describing the forecast. These standards are supported by software developed to help generate and validate the metadata. The white paper is available through the project website and the software is available through the [project GitHub page](). We are preparing the white paper for publication in a peer reviewed journal.

Objective 2.
The official launch of the NEON Ecological Forecasting Challenge is defined by the completion of: a web page describing the forecast challenge themes and rule; software used to process NEON data, generate forecasts, evaluate forecasts, and visualize forecast that is available through the project GitHub page; and a server running on NSF-funded Jetstream (part of XSEDE) where teams can download processed NEON data, download NOAA weather forecasts for each NEON site, submit forecasts, and see forecast evaluations (see figure below). The launch was announced through the EFI listserv, twitter, an AGU Town Hall session, ecology-related listservs, and personal networks. As of February 1, 2021 we have 30 teams officially registered to participate and expect a number more to join. The Challenge will run for the full length of the RCN project and serves as a focal point for the network. To support the cyberinfrastructure required in the NEON Ecological Forecasting Challenge, we initiated an "External Collaborative Partnership" with NSF-funded Cyverse to provide technical support for the Cyberinfrastructure used in the NEON Ecological Forecasting Challenge and storage resources on their Data Store.
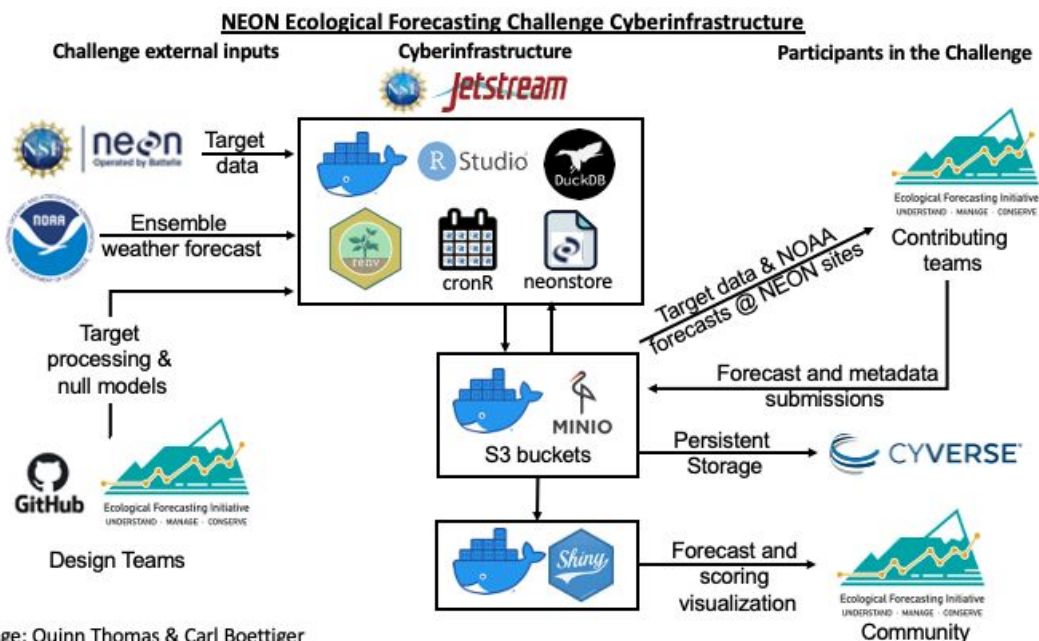

Image: Quinn Thomas & Carl Boettiger

Objective 3.
Education Working Group members are leading a manuscript that conducted a literature search, discussed with experts, and conducted a survey of forecasting professionals to better understand operational vocabulary associated with the emerging field of ecological forecasting to create the forecast definition, "an estimate, and the associated uncertainty of that estimate, about an out-of-sample state of a system". The group then placed this definition within a nested framework of ecological forecasting to facilitate communication, improve environmental decision making, and encourage diverse involvement in the field. The group is also compiling a short 1-page resource for guidance counselors and professors working with students to provide

suggestions for courses that are helpful for students interested in ecological forecasting. RCN steering committee members and EFI members taught and advised students this past summer in the Sustainable Land and Water REU and have collaborated with colleagues at the GeoScience Alliance to apply for and receive NSF funding for a GeoScience Alliance meeting to be held next September in North Carolina.

Objective 4.
We created new software (R package: neonstore) to provide a high-level user interface for downloading and storing NEON data products. While each of NEON data products consist of hundreds or thousands of individual files, unlike 'neonUtilities', this package will avoid repeated downloading, provides persistent storage, and improves performance. 'neonstore' can also construct a local 'duckdb' database of stacked tables, making it possible to work with tables that are far too big to fit into memory. We created an R package (EFIstandards) that includes a description of the ecological forecasting standards, a metadata validator, helper functions, and example vignettes. We created an R package (noaaGEFSpoint) that downloads and processes NOAA weather forecasts for each NEON site.

Objective 5.
We generated videos from our session at our May 2020 virtual meeting on the demand for NEON-enabled ecological forecasting by partners and stakeholders. Partners are included in the NEON Ecological Forecasting Challenge design themes. Our virtual meeting included 77 registered individuals from non-academic institutions.

Objective 6.
As discussed above, we developed a white paper, vignettes, and R code that describe standards for archiving forecasts. The standards are a critical foundation for future work in the RCN to synthesize patterns of predictability across ecological systems and scales.

Opportunities for training and professional development.

Multiple opportunities for training and professional development have been provided by the RCN to the broader EFI community as well as specifically for graduate students and postdoctoral scholars.

First, our RCN has an active graduate student association (EFISA) that meets monthly, resulting in 12 meetings in 2020 and has over 70 members. Graduate students developed their own operating principles and procedures and defined the goal of the association to provide a community of students who have expertise in a diverse array of fields, but who all share a common interest of improving and contributing to the development and application of ecological forecasts. As a result, knowledge exchange and community-building are two of their foremost goals. Along with these aims, the EFISA strives to serve the student community by developing technical and professional development skills, providing peer support, and advancing career aims.

In May 2020, the graduate student association organized a virtual meeting that provided a platform for new and current student members to network, share resources, and educate one another. The workshop included sessions intended to engage new members, update on ongoing projects within EFI, provide training in forecasting methods, develop specific focus groups for student-led projects, and ratified the Operating Principles and Procedures which will continue to guide the future of the student association. John Foster (Boston University) created a [primer on ecological forecasting](#) that he presented at the workshop and which is available on the [EFI YouTube Channel](#). Overall, the workshop reached over 40 students, many of whom were new to EFI. The workshop was coordinated wholly by student co-chairs (Whitney Woelmer, Virginia Tech; Millie Chapman, University of California, Berkeley; Dave Klinges, University of Florida), thus providing professional development in virtual workshop planning. The graduate student association has also gained training in team science and collaboration software development through the creation of a website ([an Rshiny application](#)) that provides a map of Ecological Forecasting Initiative membership.

Second, students and post-docs have professional development opportunities as leaders within the RCN. All five design teams are being led by graduate students or post-docs for the NEON Ecological Forecasting Challenge (Terrestrial Carbon and Water Flux: Alex Young, SUNY - College of Environmental Science & Forestry); Tick Populations: John Foster (Boston University; Phenology: Kathryn Young, Boston University; Beetle Communities: Anna Spiers, University of Colorado, Boulder; Aquatics: Ryan McClure, Virginia Tech, Sarah Burnet, University of Idaho, James Guinnip, Kansas State University). Their leadership roles involved coordinating meetings of the design teams and guiding the teams to decide what NEON data to forecast, how to process the NEON data, and how to generate generic forecasts. Students and post-docs are leading manuscripts that are currently being developed. These manuscripts include one about how the definitions of a forecast vary across fields (Anna Sjodin, University of Idaho and Gretchen Stokes, University of Florida), one about 10 Simple Rules for gaining training in emerging fields (Whitney Woelmer, Virginia Tech and Elizabeth Mohr, Montana State University), and one about the theory of ecological forecasting (Abby Lewis, Virginia Tech and Amanda Gallinat, Utah State University). Graduate students have gained professional leadership experience by serving on the RCN steering committee. Our steering committee currently has two graduate students (Whitney Woelmer from Virginia Tech and Alyssa Willson at Notre Dame) that provide important guidance for making the RCN serve the needs of early career scientists. Willson has compiled over 100 online educational resources and assessing where there are gaps that need new material created. Finally, post-doc Anna Sjodin from the University of Idaho has led the DEI book group conversations and moderated the DEI Nov 19 Q&A sessions with panelists.

We have hosted two book clubs and currently are in the middle of our third book. Our first group, with nine participants, met over the summer to discuss racial and inequity issues highlighted in the book "The Years That Matter Most: How College Makes or Breaks Us". This past semester we have had a group of 48 participants discussing spatial and temporal statistics

using the book "Spatio-Temporal Statistics with R" as a guide. Our third book club which discussed "Caste: The Origins of Our Discontent" had 10 participants.

RCN steering committee members, Quinn Thomas (Virginia Tech), Michael Dietze (Boston University) and Jason McLachlan (University of Notre Dame) were instructors in the Near-term Ecological Forecasting Initiation (NEFI) course and taught forecasting material related to the RCN.