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DEPARTMENT OF COMMERCE
RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

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AWARD INFORMATION	
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3. Project Title: The Cooperative Institute for Great Lakes Research (CIGLR): A Proposal to the Office of Oceanic and Atm	
4. Award Period of Performance Start Date: 07/01/2017	5. Award Period of Performance End Date: 06/30/2023
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR	
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8. Title:	
9. Email: gdick@umich.edu	10. Phone Number: 734-763-3228
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13. Title: Asst Director Contract Administration	
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REPORTING INFORMATION	
Signature of Submitting Official: Becca Timmermans	
16. Submission Date and Time Stamp: 04/28/2022	17. Reporting Period End Date: 03/31/2022
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RECIPIENT ORGANIZATION	
20. Recipient Name: REGENTS OF THE UNIVERSITY OF MICHIGAN	
21. Recipient Address: 503 THOMPSON STREET, ANN ARBOR, MI 48109-1340 USA	
22. Recipient UEI: GNJ7BBP73WE9	23. Recipient EIN: 386006309

ACCOMPLISHMENTS

24. What were the major goals and objectives of this project?

The Cooperative Institute of Great Lakes Research (CIGLR) leads new research, trains the next generation of scientists, and turns research into action for safe and healthy Great Lakes communities. CIGLR was established in 2017 to accelerate NOAA's mission in the Great Lakes. CIGLR is hosted by the University of Michigan's School for Environment and Sustainability (SEAS) and is a partnership between NOAA's Great Lakes Environmental Research Lab (GLERL), and 9 universities, 2 NGOs, and 3 private businesses that span all 5 Great Lakes on both sides of the US-Canada border.

The following goals are designed to help CIGLR achieve its mission:

1. Research institute. CIGLR operates a productive research institute that complements NOAA GLERL's workforce with a highly-skilled, permanent group of research scientists, technicians, and staff that is fully integrated in GLERL's scientific enterprise and serves to expand GLERL's research expertise.

2. Regional consortium. CIGLR expands GLERL's intellectual capacity and research infrastructure by building strong partnerships with universities, NGOs, and private-sector partners who share similar research and management goals in the Great Lakes. Consortium partners include 9 universities and 5 private sector organizations that collaborate with CIGLR and NOAA GLERL to conduct research, transition research to operations, and engage with stakeholders. Regional Consortium partners include: Central Michigan University, Cornell University, Grand Valley State University, University of Michigan, Michigan State University, University of Minnesota-Duluth, Ohio State University, University of Windsor, University of Wisconsin-Milwaukee, Fondriest Environmental, Great Lakes Environmental Center, LimnoTech, The Nature Conservancy, National Wildlife Federation.

3. Science translation. CIGLR helps translate NOAA research in the Great Lakes into action-oriented, science-based products that meet the needs of end-user stakeholders like natural resource managers, businesses, public utilities, and citizen users of data.

4. Engagement (ECO Program). CIGLR supports informed decision making by working directly with legislators, resource managers, and other stakeholders to develop the research programs, tools, and information needed for decision making that promotes sustainability in the Great Lakes. We work directly with those who rely on our research tools and products to facilitate the co-production of research outcomes.

5. Career development (ECO Program). CIGLR fosters the development of a diverse, skilled workforce by providing career training for undergraduates, graduate students, and postdoctoral fellows who will become the next generation of NOAA and Great Lakes scientists. We strive to shape a workforce that is not only skilled in NOAA mission-related research priorities, but also one that is rich in diversity in an inclusive environment.

6. Outreach & communications (ECO Program). CIGLR advances Great Lakes environmental literacy by communicating the value

25. What was accomplished under these goals?

Despite continuing pandemic conditions, we made significant progress in each of our research themes this period:

Theme 1. Observing systems & advanced technology
We completed 28 HAB monitoring cruises in Lake Erie and Saginaw Bay to generate data for stakeholders and HAB forecast models. We funded and participated in the first basin-wide coordinated winter sampling event in the Great Lakes. Cooperative glider operations with RAEON set new highs for days at sea (116), number of deployments by CIGLR (7), and continuous coverage of an operating area by multiple gliders. We deployed data buoys in Lakes Michigan (2) and Erie (3) and operated 10 spotter wave buoys through community partnerships to continuously monitor ecosystem parameters and support model development/validation. We contributed to evaluations of the MBio Toxin System for rapid detection of cyanotoxins.

Theme 2. Invasive species & food-web ecology
Our work on the Lake Erie Cooperative Science Monitoring Initiative (CSMI) provided the most up-to-date information on benthic organisms, including invasive mussels, and improved understanding of HAB dynamics and the impacts of hypoxia on manganese and phosphorus accumulation. Our work on Lake Michigan CSMI provided estimates of primary production and food web components, and evaluated the impact of invasive mussel veligers on perch growth. We continued a comprehensive Great Lakes 'omics program to study ecosystem change and made substantial progress towards the creation of a database that will house all Great Lakes omics data.

Theme 3. Hydrometeorological & ecosystem forecasting
We advanced the research-to-operation transition of the Great Lakes short-term ice forecast by engaging with potential user groups to understand the usability of existing ice data products, user information needs, and preferences for user interface with data products. We coupled sea ice, wave, and storm surge models to develop a western Alaska operational storm surge forecast. We continued to improve Runoff Risk decision support tools' accuracy and demonstrated their effectiveness for improving water quality and crop yield. We addressed gaps in navigational support by extending the FVCOM operational hydrodynamic model grid into ports and large rivers that are not resolved in the existing NOAA modeling infrastructure. We contributed to the development of a new Great Lakes Earth System Model by improving winter physical datasets and hydrodynamic-ice-wave simulations. Our work improved water prediction in the region by providing a better estimate of the total groundwater flux to the Great Lakes and the impacts of groundwater on nearshore ecosystems. We introduced a novel machine learning model for Great Lakes wave forecasting, which may be an alternative for numerical-model based wave forecasting. We developed a new high-resolution model with coastal flooding capacity, representing the first hydrodynamic modeling of meteotsunami-induced coastal flooding for the Great Lakes.

Theme 4. Protection & restoration of resources
We engaged state, local, corporate, and philanthropic partners to generate support for ecological and sediment restoration in the

ACCOMPLISHMENTS *(cont'd)*

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

CIGLR had another strong year offering employee training and professional development opportunities, in accordance with the CIGLR Employee Handbook that identifies expectations, evaluation processes, and career development resources.

Research Scientists are offered mentoring and development opportunities to help ensure their professional success.
We provide support to achieve scholarly publication goals, establish a successful funding record, mentor students, engage in professional service, and develop engagement activities that complement their research.

As outlined in the CIGLR Postdoc Handbook, Postdoctoral Fellows follow an Individual Development Plan (IDP) that includes a statement of career goals, a strategy to achieve career goals, and a timeline for success. Postdocs develop a research proposal that includes clear hypotheses with testable predictions and receive coaching on the job application and interview process. During the reporting period, two new postdocs developed an IDP and research proposal and 3 continuing postdocs received career coaching toward fulfilling IDP goals. One of the continuing postdocs secured a faculty position at a different university and another secured a position at an environmental consulting firm.

Research/Administrative Staff develop an annual goal setting and development plan tailored to their job responsibilities, individual career aspirations, and development needs. Each development plan includes at least one training activity and a science dissemination goal. Three Research/Administrative Staff were promoted to higher-level positions during the reporting period, reflecting their growing level of skill, responsibility, and contribution.

All CIGLR employees have access to professional development resources offered by the University of Michigan, such as grant writing workshops, short courses on topics such as career development and leadership, and statistics and data science workshops. CIGLR and the UM School for Environment and Sustainability provide financial support for professional development activities.

During the reporting period, CIGLR supported the following professional development activities:
•Research staff, students, and postdocs presented 14 oral or poster presentations at scientific conferences and workshops
•Research staff and students led or co-authored 5 peer-reviewed and 10 non-peer-reviewed papers
•Research staff and postdocs presented at 10 CIGLR Science & Snacks discussions
•Staff and students attended the following training courses/workshops
-Cultivating a Culture of Respect: Sexual Harassment and Misconduct Awareness
-Addressing Implicit Bias
-Unconscious Bias in Recruiting and Hiring
-Let's Talk About Implicit Bias: Our Role, Responsibility, Action, and Accountability
-Bioinformatics training
-Echoview software training sessions

27. How were the results disseminated to communities of interest?

CIGLR had a strong publication and presentation record during this period that allowed us to have high impact within our scientific disciplines. Our research projects produce scholarly publications, technical reports, and conference presentations that disseminate results to scientific audiences, as well as informational and data-delivery webpages. Section 29 and Appendix 2 contain a summary of project-produced products that communicate research results.

Dissemination of our science was enhanced by the Outreach & Communications element of our ECO Program, which is designed to translate and disseminate CIGLR research outcomes to support informed decision making, increase interest in Great Lakes science careers, and promote a culture of Great Lakes stewardship. We estimate that CIGLR's Outreach & Communications efforts have reached more than 1.1 million people during this reporting period through the activities described below.

Our key messages are formulated using input gathered from CIGLR leadership and principal investigators, and modified as needed for target audiences. CIGLR's target audiences include the CIGLR Regional Consortium, NOAA (e.g., GLERL, CIAO, OAR, GLRCT), other NOAA Great Lakes programs (e.g., Sea Grant, GLOS, GLISA), SEAS leadership and communication team, the general public, news media, and stakeholders (e.g., resource managers, industry, government officials).

CIGLR's primary communication methods include:
•CIGLR website - 43K average hits/month over this period
•Social media - 7K followers across all platforms (Twitter, Facebook, Instagram)
•You Tube - 86 original videos featuring CIGLR research projects, staff profiles, and summer fellow highlights
•Flickr - 2,149 publicly-available photos with descriptive captions, in 17 subject-matter albums
•CIGLR Quarterly e-newsletter - 4 produced this period, 794-person distribution list, 39% open rate
•Ripple Effect Annual Magazine - 2,384 subscribers
•CIGLR Minute videos - 7 produced this period and shared on social media, the CIGLR website, and You Tube
•NOAA OAR Hot Items - 21 articles contributed this period
•News media - 309 news stories featured CIGLR and our research this period
•Monthly activity and accomplishments updates to GLERL and SEAS leadership and communications teams

CIGLR's outreach activities typically center on interactive informational tables at community events and scientific conferences. During the COVID-19 pandemic, we transitioned to programming through social media and virtual outreach events to engage and educate our public audience. We reached 8,540 participants during 3 virtual outreach events this period, including the MSU Science Festival Expo (April 2021), IAGLR (May 2021), and the SEAS Green Career Fair (January 2022).

We work with our Regional Consortium partners, NOAA GLERL, and other NOAA programs to expand our outreach and communications efforts across the Great Lakes basin. Our continued participation in NOAA communications and outreach groups allows us to coordinate our efforts with NOAA programs across the basin, resulting in broader impact, cohesive messaging, and increased visibility for NOAA in the Great Lakes. We are active members of the GLERL Information Services Communications Group

ACCOMPLISHMENTS *(cont'd)*

28. What do you plan to do during the next reporting period to accomplish the goals and objectives?

CIGLR's Award Action Request for a 12-month no-cost extension of the parent award was approved by NOAA on April 15, 2022, thereby extending our end date to 6/30/23. As we complete the final months of our 5-year Cooperative Agreement award and enter the no-cost extension period, we are working in earnest to complete remaining goals and objectives in 26 research projects. Balances remain in the 26 projects due to delayed receipt of research awards (3-6 months after project start dates), personnel lapses during recruitment after staff departure, and delays in project execution due to COVID-19. There will be no additional amendments or changes to the current plan of work, scope of project, or budget during the extension period. While we will continue to foster ongoing collaborative research and infrastructure sharing with the Regional Consortium during the extension, all new interactions and engagements with partners (e.g., research, programmatic awards, annual meeting) will occur under our 5-year renewal award. In the ECO Program, ongoing engagement and career training activities will be completed during the no-cost extension period, while all outreach and communications efforts will transition to the renewal award at the end of the original award period (June 30, 2022).

PRODUCTS

29. Publications, conference papers, and presentations

CIGLR maintained a strong record of publication and presentation this period, with 30 peer-reviewed publications and 81 conference presentations. A 2020 paper by Fujisaki-Manome et al. in the Journal of Hydrometeorology won the 2021 Outstanding Science Paper Award by NOAA OAR. Peer-reviewed publications, non-peer reviewed publications, and presentations are included in Appendix 2–Products. A complete list of scholarly publications will be submitted to NOAA IR by 7/31/22.

Other products during the reporting period include the following websites, which provide access to CIGLR data and data products:

CIGLR parent
•https://ciglr.seas.umich.edu/

Building Coupled Storm Surge and Wave Operational Forecasting Capacity for Western Alaska
https://gm-ling.github.io/ALCOFS-R/ - Alaska Coastal Ocean Forecast System
http://www-personal.umich.edu/~hghu/index.html - sea ice model

HABs Monitoring, Forecasting and Genomics for the Great Lakes
•https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/rtMonSQL.php - monitoring data for western Lake Erie and Saginaw Bay
•https://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:0190201 - NCEI archive
•https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/bulletin.html - Lake Erie HAB Bulletin

Great Lakes CoastWatch Research Assistant for NOAA CoastWatch Program Element
•https://coastwatch.glerl.noaa.gov – NOAA CoastWatch Great Lakes Node
•https://coastwatch.glerl.noaa.gov/ice_class/ice_class.php - ice type classification
•https://coastwatch.glerl.noaa.gov/wind/wind.php - wind imagery
•https://coastwatch.glerl.noaa.gov/nrcs/nrcs.php - Normalized Radar Cross Section

GLISA Climate Modeling Workshop
•http://glisa.umich.edu/project/2021-great-lakes-climate-modeling-workshop/

2020 Annual Climate Trends and Impacts Summary for the Great Lakes Basin
•http://glisa.umich.edu/resources/annual-climate-summary

2021-22 GLWQA Annex 9 Syntheses: Annual Climate Trends and Impacts Summary for the Great Lakes Basin and 50th Anniversary Lake by Lake Retrospectives
•https://glisa.umich.edu/sustained-assessment/ - 50 year climate retrospectives

PRODUCTS *(cont'd)*

30. Technologies or techniques

CIGLR's cutting-edge research is at the forefront of technology and methods development for advancement of Great Lakes science. New developments this period advanced our ability to forecast, monitor, and observe conditions in and around the lakes. These include:

•Great Lakes Omics. We developed new software to produce universal (covering all domains and viruses) reference databases for taxonomy, compounds, reactions, non-coding RNAs, and proteins. We added new features to our existing metagenome pipeline to predict organism-specific compound production and metabolic interactions between organisms. We have begun development of a database to store pipeline results and make them available via a user-friendly web-interface.

•Metagenomic and eDNA approaches for early detection and community impact of Great Lakes invasive species. We developed a new methodology that uses eDNA and eRNA to accurately detect species presence and estimate relative abundance. This new method is easily modified and can be applied to monitoring different species within the Great Lakes or elsewhere in the world. We developed better eDNA-based assays for distinguishing legacy DNA, estimating the age of eDNA, and monitoring new invasions where the number of organisms is very low and otherwise not possible to detect.

•Objective methods for thinning the frequency of reforecasts while meeting postprocessing and model validation needs. We developed a CCA-related technique to sub-sample meteorological reforecasts, without negatively impacting hydrologic forecast quality and associated decision support. We expect that the technique we have developed will be useful for hydrological applications, but this is still in the process of being confirmed by NOAA collaborators.

•Implementation of the GLOS Buoy and Mobile Platform Observing Systems. We made the first winter air deployment of a lightweight, hand-deployable wave observation buoy system in Lake Michigan. With additional development of a drogue, or lightweight mooring, this technology may provide observations at low enough cost to justify deployments in locations where infrequent but extreme ice conditions could cause buoy loss.

•Lake Champlain Hydrodynamic Flood Forecasting System. We produced the first lake flood forecasting system that uses inflows from the National Water Model. The new NWM version 2.1 has its model domain extended to Canada based on work by the project team. Floodplain is included in the FVCOM domain to model both seasonal and short-term water level variations. As part of this effort, we developed the first Lake Champlain wave model capable of predicting waves in flood prone areas.

•Coastal Coupling in Large Lakes for Total Water Prediction. We developed a high-resolution model with coastal flooding simulation capacity that is novel in Great Lakes hydrodynamic modeling. This work is the first hydrodynamic modeling of meteotsunami-induced coastal flooding for the Great Lakes.

31. Inventions, patent applications, and/or licenses

Nothing to Report

PRODUCTS *(cont'd)*

32. Other products

In addition to scientific publications and presentations, CIGLR developed a number of other products this period to support NOAA's mission in the Great Lakes, including maps, models, outreach materials, and news articles. We also submitted 14 proposals for $7.5M of leveraged funding outside of the CIGLR Cooperative Agreement.

MAPS
•CoastWatch Great Lakes map products
•FVCOM nearshore circulation and temperature differentials
•Snow cover, temperature, and precipitation anomalies for the 2020 annual climate summary
•Reanalysis Lake Surface Temperature figures for Lake Erie and Lake Michigan from 1995-2020

MODELS
•Machine learning model based on XGBoost for wave forecasting in Lake Erie
•WaveWatch III configured for Lake Superior and Lake Erie
•5-day real time sea ice forecast model for Bering-Chukchi Sea
•Arctic Sea Route model
•WRF-Hydro hydrological model of Lake Champlain-upper Richelieu River basin
•FVCOM-based Lake Champlain hydrodynamic model
•WAVEWATCH III-based Lake Champlain hydrodynamic model
•Statistical models to predict runoff risk using NWMl v2.1 output
•Extension of the Lake Superior FVCOM grid into the Duluth port and St. Louis River
•Novel coupled model able to resolve: (1) coastal model grid resolution and wetting and drying process in low-lying zones, (2) coastal infrastructure, including breakwaters and associated submerging and overtopping processes, and (3) wind wave-current coupling.
•Data assimilative hydrodynamic model for the Great Lakes

PROPOSALS FOR LEVERAGED FUNDING
•'Omics-informed mapping of Microcystis predation defense trade-offs to improve Great Lakes harmful algal bloom models. Michigan Sea Grant. $253,426
•Quantifying the Role of Microcystis Resuspension on HABs in Coastal Lake Erie Using Multidisciplinary Approaches. US Coastal Research Program. $289,254
•Advancing the Lake-Coupling Techniques for the Unified Forecast System (UFS). NOAA. $779,133
•Supporting decision-making for a vital waterway in the Great lakes by machine learning model-based lake ice forecasting. The Michigan Institute for Data Science 2021 Propelling Original Data Science (PODS) Grants. $30,000
•Improving Lake-Effect Snow Forecasting Capabilities via Advanced Coupling Techniques in NOAA's Unified Forecast System (UFS). NOAA. $750,000

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

CIGLR Administration
Gregory Dick, Director, University of Michigan (started September 2021)
Thomas Johengen, Acting Director, University of Michigan (through August 2021)
Mary Ogdahl, Program Manager, University of Michigan

CIGLR Research Institute Principal Investigators
Dmitry Beletsky, Research Scientist, University of Michigan
Subba Rao Chaganti, Assistant Research Scientist, University of Michigan
Michael Fraker, Assistant Research Scientist, University of Michigan
Ayumi Fujisaki-Manome, Assistant Research Scientist, University of Michigan
Casey Godwin, Assistant Research Scientist, University of Michigan
Thomas Johengen, Research Scientist, University of Michigan

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS *(cont'd)*

34. Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Senior personnel changes during the reporting period were related to the completion of organizational changes following the unexpected departure of the former CIGLR Director, Bradley Cardinale, in 2020. Dr. Tom Johengen served as the NOAA-approved Acting Director of CIGLR until September 1, 2021, when Professor Greg Dick became the new permanent Director. This change followed an approved Award Action Request submitted by the University of Michigan. Professor Dick is a tenured full professor (50%) in the University's Department of Earth and Environmental Sciences (EES), as well as a full professor (50%) in the School for Environment and Sustainability (SEAS) where CIGLR is administered. Professor Dick's research has increasingly focused on the Great Lakes where he has collaborated with scientists from CIGLR, NOAA GLERL, and across the region. His work on Great Lakes cyanobacterial blooms has important applications in public and environmental health, and has the potential to inform policy on water quality and water resources management. He previously served as the Associate Chair for Curriculum and Undergraduate Studies in EES at U-M. Dr. Dick's accomplishments highlight his qualifications for managing the administrative functions of CIGLR, including oversight of financial management and the research portfolio, and mentoring and support of CIGLR's personnel. His vision and leadership will galvanize CIGLR and GLERL's role as leaders of aquatic sciences in the Great Lakes.

The other changes in senior personnel were related to CIGLR's Associate Director position. In the absence of an Associate Director, CIGLR developed an interim organizational structure to cover the roles identified for the Associate Director through a team of Theme Leads. Theme Leads are CIGLR principal investigators who provide scientific leadership for CIGLR by communicating and coordinating ongoing collaborative research, personnel needs, and new funding opportunities with their corresponding NOAA GLERL Branch Chiefs. The Theme Leads include Dr. Casey Godwin (Ecosystem Dynamics theme), Dr. Ayumi Fujisaki-Manome (Modeling and Forecasting theme), and Mr. Russ Miller (Observing Systems theme). The AAR for this interim organizational structure was approved in June 2021.

Following the hire of Greg Dick as the new CIGLR Director, we submitted an AAR describing a long-term organizational structure in which we retain the Theme Leads and hire an Associate Director to form a robust leadership team. Given the volume and scientific breadth of collaborative CIGLR-GLERL research, which has grown substantially over the past five years, the effective research coordination and communication achieved by the three Theme Leads under the interim structure cannot be replicated by a single Associate Director. We chose to retain the Theme Leads to maintain their critical functions in research coordination, personnel management, and project management, and hire an Associate Director to assist the Director in representing CIGLR at the highest levels, engage the Regional Consortium, and pursue development of strategic research areas and initiatives. The long-term organizational structure AAR was approved by NOAA in February 2022.

Shortly thereafter, CIGLR began an internal search for an Associate Director. An excellent candidate was identified in Dr. Sarah Hughes, who is an Associate Professor in SEAS with expertise in social science, water policy, and equity and environmental justice. Professor Hughes's expertise will be valuable to CIGLR as a leader of our social science programs, including mentoring postdocs

35. What other organizations have been involved as partners?

Consortium lead investigators (CIGLR Council of Fellows reps)
John Bratton, LimnoTech
Patrick Doran, Nature Conservancy
Aaron Fisk, University of Windsor
Steve Fondriest, Fondriest Environmental
Sara Hughes, University of Michigan
Rebecca Klaper, University of Wisconsin-Milwaukee
Phani Mantha, Michigan State University
Dennis McCauley, Great Lakes Environmental Center
Lars Rudstam, Cornell University
Mike Shriberg, National Wildlife Federation
Al Steinman, Grand Valley State University
Bob Sterner, University of Minnesota Duluth
Don Uzarski, Central Michigan University
Chris Winslow, Ohio State University

CIGLR Executive Committee
Gregory Dick – Director, CIGLR, University of Michigan (Ex-Officio) (after August 2021)
Tom Johengen – Acting Director, CIGLR, University of Michigan (Ex-Officio) (until September 2021)
Carl Gouldman – Director, U.S. IOOS Office, NOAA National Ocean Service
Deborah Lee – Director, NOAA GLERL (Ex-Officio)
Brad Orr – Associate VP, Natural Sciences and Engineering, University of Michigan
Jonathan Overpeck – Samuel A. Graham Dean, School for Environment and Sustainability, University of Michigan
Steven Thur – Director, National Centers for Coastal Ocean Science, NOAA National Ocean Service

Subawardees
Regional Consortium Principal Investigators
Jon Allan, University of Michigan
Jose Andres, Cornell University
Karen Alofs, University of Michigan
Bopi Biddanda, Grand Valley State University
Tracy Boyer, University of Wisconsin-Milwaukee
John Bratton, LimnoTech

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS *(cont'd)*

36. Have other collaborators or contacts been involved?

Significant NOAA collaborators included:
Eric Anderson, NOAA GLERL
Nancy Beller-Simms, NOAA CPO
Ellen Brody, NOAA Sanctuaries
Philip Chu, NOAA GLERL
Jennifer Day, NOAA GLERL
Ashley Elgin, NOAA GLERL
Reagan Errera, NOAA GLERL
Jesse Feyen, NOAA GLERL
Dustin Goering, NOAA NWS
Deborah Lee, NOAA GLERL
Brent Lofgren, NOAA GLERL
Doran Mason, NOAA GLERL
Steve Pothoven, NOAA GLERL
Mark Rowe, NOAA GLERL
Steve Ruberg, NOAA GLERL
Ed Rutherford, NOAA GLERL
Julie Sims, NOAA Restoration Center
Ivanka Stajner, NOAA NWS
Heather Stirratt, NOAA OCM
Craig Stow, NOAA GLERL
Fred Toepher, NOAA NWS
Hendrik Tolman, NOAA NWS
Hank Vanderploeg, NOAA GLERL
Andrea Vander Woude, NOAA GLERL
Jia Wang, NOAA GLERL

IMPACT

37. What was the impact on the development of the principal discipline(s) of the project?

With a research portfolio spanning the most pressing issues in the Great Lakes, CIGLR makes important contributions to the science and forecasts that protect life and property across the region. Research highlights this period included:

Observing systems: We improve spatial and temporal coverage of key meteorological, hydrodynamic, and biological variables throughout all of the Great Lakes to support the development of improved databases and forecasts within 4 priority areas: climate change impacts, ecosystem and food web dynamics, protection of public health, and navigation safety and efficiency. Our physical limnologists and biophysical modelers are increasingly utilizing the highly resolved, 3D water column data generated by our glider missions. Our newer shallow-water operating systems open up new applications, such as mapping hypoxia formation in the central basin of Lake Erie. We also continue to collaborate with other federal partners from EPA and USGS to expand capacity in the region and plan regional applications, typically in support of the EPA Coordinated Science Monitoring Initiative.

Harmful algal blooms: Our HAB monitoring program has become a benchmark for assessing the status and trends of HABs in western Lake Erie and Saginaw Bay. Our experimental results on Microcystis buoyancy will be used to help interpret remote sensing imagery from western Lake Erie and Saginaw Bay, and could be used to inform potential future models of bloom transport. The results of our monitoring data are being used in analyses that will support adaptive nutrient management in the Great Lakes under Annex 4. In particular, our statistical modeling helped resolve the apparent absence of correlation between Maumee River phosphorus loads and phosphorus concentrations in western Lake Erie. By including spatial correlations, the model showed that the load does in fact correlate with lake concentrations, but the locations in the lake each respond to the load differently because of the impact plume. This finding will be critical for understanding how the lake responds to loads from the watershed.

From our 'omics research, we published a review paper (Dick et al. 2021) that represents a major resource for the cyanobacterial HABs community. It not only documents current knowledge, but also highlights areas that need further investigation. Our research will help fill some of these gaps in current knowledge and eventually allow for better cHABs control and models of their formation, duration, intensity, and toxicity. We also created a collection of Microcystis laboratory cultures, which will serve as a foundation for biological studies of this HAB-forming organism into the future. These are among the first strains of Microcystis to be isolated and have their genomes sequenced from the Great Lakes, thus providing a unique and valuable resource for the Great Lakes community.

Winter limnology: Across multiple projects, we made a tremendous impact on our understanding of winter conditions and processes across the Great Lakes. As a follow-on to our 2019 Winter Limnology Summit, we funded and participated in a basin-wide coordinated winter monitoring event. Nineteen organizations in the US and Canada collected foundational limnological data from 49 locations across all 5 Great Lakes. Our operational innovations with small buoy systems may open the door to wave observations through winter in some locations that are important to commercial shipping. We used observational data from ice and current/wave

IMPACT *(cont'd)*

38. What was the impact on other disciplines?

CIGLR makes significant contributions to other disciplines through our interdisciplinary expertise and mission to produce science outcomes for society. Our research during this period continued to improve tools for agricultural producers and laid the foundation for exploring environmental justice aspects of flooding in the Great Lakes.

Agriculture: We continue to work with NWS to improve the accuracy of the Runoff Risk decision support tools and evaluate their effectiveness for improving water quality, with the goal of providing farmers with an easy-to-implement nutrient management practice that maximizes profit while protecting water quality. Operational Runoff Risk tools offer real-time forecasting guidance about when to avoid applying fertilizers due to the likelihood of a runoff event. In one research project, we are using watershed models to estimate reductions in nutrient runoff and impacts to crop yield when fertilizers are applied during best-case (low runoff risk) and worst-case (high runoff risk) conditions. Our model results not only predicted loading reductions in key nutrients that fuel HABs, but also increased crop yields when fertilizers were applied during low runoff risk conditions. Our results demonstrate Runoff Risk tools' potential to reduce nutrient runoff while boosting yield, demonstrating their dual benefit in agricultural and environmental sectors. In a second project, we are collaborating with NWS to develop the next generation of Runoff Risk tools to use output from the NOAA National Water Model. The improved tools feature finer-scale forecasts and continuous improvements, allowing farmers to see future conditions in their local area and plan fertilizer applications more precisely. By building a framework that relies on the National Water Model, the new support tools will rely on forecasts with higher spatial resolution, improved accuracy, and a framework that can be transferred to other regions because the underlying hydrological forecast model is operational over the entire CONUS.

Environmental Justice: We began a new collaborative research project with the NOAA Climate Program Office focused on the inequitable impacts of flooding on communities throughout the watersheds that surround the Great Lakes. We are working to understand the needs, existing capacity, and opportunities to expand access to climate services. With a focus on the needs of stormwater managers, the information we are generating will lead to a better understanding of socioeconomic discrepancies in water utility infrastructure, guide future policies that address those discrepancies, and evaluate potential options for adapting to extreme events due to variations and long-term changes in the climate system. We are compiling spatial data describing exposure, vulnerability, and risk of people, places, and things of concern to communities throughout the region. We will ultimately align potential adaptation options to the types of flooding exposure, vulnerability, and risk that Great Lakes communities face. In another project, we are incorporating historical analysis and systemic discrimination assessment into our efforts to build support for pressing ecological and sediment restoration in the Detroit and Rouge River Areas of Concern (AOCs). We are crafting a storyline that is rooted in science and restoration, yet resonates with a broader constituency for the betterment of communities, people, the city, the region, the state and the Great Lakes. Our approach to analyzing flood impacts combines GIS modeling methods with econometric analysis, which has the potential to provide a model for future environmental justice assessments.

39. What was the impact on the development of human resources?

Please see attachments.

IMPACT *(cont'd)*

40. What was the impact on teaching and educational experiences?

Please see attachments.

41. What was the impact on physical, institutional, and information resources that form infrastructure?

Please see attachments.

Attach a separate document if more space is needed for #6-10, or #24-50.

IMPACT *(cont'd)*

42. What was the impact on technology transfer?

Please see attachments.

43. What was the impact on society beyond science and technology?

Please see attachments.

Attach a separate document if more space is needed for #6-10, or #24-50.

IMPACT *(cont'd)*

44. What percentage of the award's budget was spent in foreign country(ies)?

0 , Please see attachments.

CHANGES/PROBLEMS

45. Changes in approach and reasons for change

Please see attachments.

Attach a separate document if more space is needed for #6-10, or #24-50.

CHANGES/PROBLEMS *(cont'd)*

46. Actual or anticipated problems or delays and actions or plans to resolve them

Please see attachments.

47. Changes that had a significant impact on expenditures

Please see attachments.

Attach a separate document if more space is needed for #6-10, or #24-50.

CHANGES/PROBLEMS *(cont'd)*

48. Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Please see attachments.

49. Change of primary performance site location from that originally proposed

Please see attachments.

Attach a separate document if more space is needed for #6-10, or #24-50.

PROJECT OUTCOMES

50. What were the outcomes of the award?

Please see attachments.

DEMOGRAPHIC INFORMATION FOR SIGNIFICANT CONTRIBUTORS (VOLUNTARY)

Gender:

- ◯ Male
- ◯ Female
- ◯ Do not wish to provide

Ethnicity:

- ◯ Hispanic or Latina/o Not
- ◯ Hispanic or Latina/o Do not
- ◯ wish to provide

Race:

- ◯ American Indian or Alaska Native Asian
- ◯ Black or African American
- ◯ Native Hawaiian or other Pacific Islander
- ◯ White
- ◯ Do not wish to provide

Disability Status:

- ◯ Yes
  - [ ] Deaf or serious difficulty hearing
  - [ ] Blind or serious difficulty seeing even when wearing glasses
  - [ ] Serious difficulty walking or climbing stairs
  - [ ] Other serious disability related to a physical, mental, or emotional condition
- ◯ No
- ◯ Do not wish to provide

Attach a separate document if more space is needed for #6-10, or #24-50.