DEPARTMENT OF COMMERCE
RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

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AWARD INFORMATION	
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13. Title: Managing Project Representative	
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REPORTING INFORMATION	
Signature of Submitting Official: Caitlin Nagler	
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RECIPIENT ORGANIZATION	
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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 10 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 10 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, Lake Superior 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 training (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.

25. What was accomplished under these goals?

We made significant progress in each of our research themes this period:

Theme 1. Observing systems & advanced technology
We completed 39 harmful algal bloom (HAB) research and monitoring cruises in Lake Erie and Saginaw Bay to generate data and decision support products for stakeholders. In the Great Lakes CoastWatch program, we developed and disseminated near real-time regional products using remotely sensed data for research, operational, and educational purposes. Building on years of past work, we are combining data from new remote sensing platforms, biophysical transport modeling, and novel in situ measurements to improve remote sensing products that support nearshore water quality monitoring in the Great Lakes. This work contributes to a key focus area of the Great Lakes Restoration Initiative (GLRI) by providing a solution to highly resolved water quality monitoring in the Great Lakes nearshore zone, where spatial heterogeneity is high and episodic events are difficult to capture with discreet sampling locations.

Theme 2. Invasive species & food-web ecology
Our work on the Lake Huron Cooperative Science Monitoring Initiative (CSMI) supported a whole-lake benthos survey; characterized food web changes; used observing systems to estimate primary production and community metabolism; modeled nearshore transport of larval fish, tributary nutrients, and phytoplankton; and investigated deep-water sinkhole ecosystems. We continued to support NOAA's omics program in the Great Lakes, including the development of a pilot Omics Core to provide technical expertise and support for omics-based projects that will help transition NOAA GLERL into the era of large biological data sets. We began a multi-year effort to develop a Great Lakes dynamical energy budget for dreissenid mussels for incorporation as a module in a larger ecosystem model. We are evaluating technologies for open water removal of invasive mussels and the following ecological effects, including the recovery of the important benthic prey species Diporeia.

Theme 3. Hydrometeorological & ecosystem forecasting
In the Great Lakes Earth System Model project, we are producing a novel in situ winter ice and wave dataset, improving ice-wave interaction modelling, and conducting future simulations of Great Lakes ice-hydrodynamic conditions.
We continued helping Runoff Risk decision support tools along the path to operations by conducting rigorous assessment of the newly developed National Water Model-based runoff risk product. We continued to support GLRI-funded research to provide decision support tools for harmful algal blooms through bloom-season monitoring, biogeochemical measurements and experiments, and modeling to link watershed nutrient loading to lake conditions. We continued our partnership with NWS to contribute to the development of the Unified Forecast System (UFS) for weather and climate research. We began a project to modernize the user interface for GLERL's Great Lakes Water Level Dashboard, to prepare the tool for future transition to operations.

Theme 4. Protection & restoration of resources

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

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 2 new postdocs developed an IDP and research proposal and 3 continuing postdocs received career coaching toward fulfilling IDP goals. One of the continuing postdocs, Dr. Yi Hong, has accepted an Assistant Research Scientist position with CIGLR and will be our new principal investigator in hydrology.

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. Five research support 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 for students, staff, and PIs:
•14 oral or poster presentations at scientific conferences and workshops
•28 peer-reviewed and 7 non-peer-reviewed papers led or co-authored
•8 CIGLR Science & Snacks presentations and discussions
•Participation in the following training courses/workshops:
-Cultivating a Culture of Respect: Sexual Harassment and Misconduct Awareness
-Unconscious Bias in Recruiting and Hiring
-Rubrics: Transparent, Consistent, and Efficient Assessment in Support of Students' Learning
-Effective Group Work
-Facilitating Discussions of Research Literature in STEM
-Concur NextGen UI Training

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.

Our research is disseminated broadly through the Outreach element of our ECO Program, which is designed to translate and promote NOAA research in the Great Lakes to multiple audiences. We communicate CIGLR research outcomes to support informed decision making, increase interest in Great Lakes science careers, and promote a culture of Great Lakes stewardship. 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). We estimate that CIGLR's Outreach efforts have reached more than 1 million people during this reporting period through the activities described below:
•CIGLR website - 38K average hits/month over this period
•Social media - 7K followers across all platforms (Twitter, Facebook, Instagram)
•You Tube - 97 original videos featuring CIGLR research projects, staff profiles, and summer fellow highlights
•Flickr - 2,297 publicly-available photos with descriptive captions, in 19 subject-matter albums
•CIGLR Quarterly e-newsletter - 3 produced this period, 817-person distribution list, 52% open rate
•Ripple Effect Annual Magazine - 2,649 subscribers
•NOAA OAR Hot Items - 6 articles contributed this period
•News media –17 media interview requests
•University of Michigan-SEAS Green Career Fair

We work with our Regional Consortium partners, NOAA GLERL, and other NOAA programs to expand our outreach 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 and participate in monthly meetings of the NOAA Great Lakes Regional Collaboration Team (GLRCT) Communications and Outreach Working Group, composed of representatives from CIs, NOAA Line Offices, Great Lakes Sea Grant Network, and GLOS. We work closely with the OAR Communications team to share CIGLR stories of interest for featuring in the OAR monthly newsletter.

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ACCOMPLISHMENTS *(cont'd)*

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

As we near the end of Year 1 of CIGLR cooperative agreement renewal, we are preparing for both new and continuing research and ECO efforts in Year 2. In addition to 5 pending Year 1 proposals, we are in the process of preparing 32 proposals for Year 2 activities.

Cooperative agreement amendments (30) will add $6.1 million to the CIGLR renewal award, for an estimated cumulative total funding level of $11.9 million by the end of Federal fiscal year 2023. Year 2 funding will support the continuation of our core research programs, such as HAB monitoring and decision support tools; advanced observing systems, including moored buoys and autonomous underwater vehicles; long-term ecological and food web research; ice forecasting; and Great Lakes omics research. We will also continue our collaboration with the US Coast Guard, NOAA, and Lake Superior State University on the Great Lakes National Center of Expertise on oil spill modeling and response (GLCOE). Specifically, we will provide proof of concept for oil detection technologies, develop an R&D information sharing portal for the GLCOE, and develop a scientific response guide for oil under ice conditions. New projects we will initiate in Year 2 include Little Rapids (St Marys River) restoration evaluation, in collaboration with the NOAA Fisheries Restoration Center and a competitively-selected consortium member. We will also begin several new collaborations with the US Army Corps of Engineers' Great Lakes Adaptive Management (GLAM) Committee, through which we will contribute to efforts to improve predictions of water level change, develop guidance on gate operation strategies to minimize biological impacts in the St. Marys River, and contribute to GLAM activities related to regulation plan evaluation and ranking by exploring trade-offs in performance under a range of hydroclimate conditions.

Additional proposals (2) include $2.3 million in funding for continuing two multi-year Bipartisan Infrastructure Law (BIL)-funded projects related to improved subseasonal to annual water level forecasting and flood mapping.

We will continue to foster collaborative research and infrastructure sharing with the Regional Consortium, specifically through holding an annual All Partners meeting, issuing an annual call to consortium members for competitive programmatic funding, and continuing to make connections between partners and NOAA scientists for new research proposal development. The annual All Partners meeting includes presentations by GLERL, CIGLR, and partners; breakout sessions on topics designed to enhance collaboration; a poster session featuring (at a minimum) all CIGLR-funded students and postdocs; and opportunities for networking and discussion. Our annual partner program competition includes postdoc fellowships, graduate student fellowships, summits and working groups, seed funding, ECO funding, and summer student fellowships.

In the ECO Program, we will continue our ongoing engagement, career training, and outreach activities. We will produce our annual magazine, "Ripple Effect", during the next reporting period and continue our strong social and digital media presence. We will continue ongoing stakeholder engagement activities related to HAB decision support tools and the GLCOE, and begin new stakeholder engagements to prepare NOAA GLERL's arctic sea ice forecast for transition to operations. In our career training

PRODUCTS

29. Publications, conference papers, and presentations

CIGLR maintained a strong record of publication and presentation this period, with 28 peer-reviewed publications and 14 conference presentations. 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 July 31, 2023.

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/

2022-23 GLWQA Annex 9 Syntheses: Annual Climate Trends and Impacts Summary for the Great Lakes Basin and Pilot Modeling Discussion
•http://glisa.umich.edu/resources/annual-climate-summary

Great Lakes CoastWatch Research Assistant for NOAA CoastWatch Program Element
•https://coastwatch.glerl.noaa.gov
•More than 1 million pages are accessed annually by users downloading data or viewing images.
•Water surface temperature contour maps were viewed more than 80,000 times during the reporting period.

Lake Erie Hypoxia Forecast Transition
•https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/hypoxiaWarningSystem.html – experimental forecast

Development of a Coupled Hydrodynamic-Wave Model using FVCOM and WAVEWATCH III
•http://ww2/res/arctic_forecast/wave/index.html - GLERL internal website

Improved Ice Modeling for the Great Lakes and the Arctic Ocean
•http://ww2/res/arctic_forecast/gcas/index.html - GLERL internal website
•http://ww2/res/arctic_forecast/gcas_assi/index.html - GLERL internal website

Great Lakes Omics
•https://sites.lsa.umich.edu/geomicro/ - project featured on PI Dick's website
•Great Lakes Atlas of Multi-omics Research (GLAMR) data portal (under development) shares raw and processed data from GLERL, CIGLR, and broader Great Lakes 'omics projects.

2022 Cooperative Science and Monitoring Initiative on Lake Huron

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

PRODUCTS *(cont'd)*

30. Technologies or techniques

•Dreissenid mussel open water control technologies. We are constructing and testing a novel dreissenid mussel removal sled for use in deep (35-45 m) water. In addition, we have corresponded with an entrepreneur, Mr. Tyler Rez, who has received an award from a veterans' funding agency to explore the feasibility of harvesting dreissenid mussels to produce commercial products. Mr. Rez will be joining some of our cruises on Lake Michigan, and we continue to discuss with him possibilities for synergy between our dual efforts. Another potentially novel aspect of this project is the application of a Diffusive Gradient Thin Film (DGT) method for measuring sediment porewater profiles of dissolved phosphorus.

•Development of a Coupled Hydrodynamic-Wave Model using FVCOM and WAVEWATCH III. We included an ice module in the WWIII forecast model during the reporting period.

•Great Lakes Omics. Our research has developed CRSIPR-based genomic tools to aid in detecting prey items in zooplankton gut contents. Our research demonstrated that microcystin toxin gene (mcyE) presence data can be used to predict toxin threshold exceedances one week prior to toxin production.

•Leveraging new satellite assets to improve remote sensing and modeling tools for monitoring and prediction of nearshore water quality in the Great Lakes. Technologies: Particle size distribution measurement capability with the LISST-200X; Techniques: Refined nearshore CPA-A approach which will be transitioned to NOAA CoastWatch upon project completion.

31. Inventions, patent applications, and/or licenses

Nothing to Report

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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.

MAPS
•All CoastWatch Great Lakes regional products are available at https://coastwatch.glerl.noaa.gov. Specific products developed during the reporting period include:
1. Daily SST contour maps: https://coastwatch.glerl.noaa.gov/contour/
2. Near real time SST contour maps: https://coastwatch.glerl.noaa.gov/nrt_contour/

MODELS
•We configured an ice module in WaveWatch III for Lake Superior and Lake Erie, offering an opportunity to replace the outdated wave forecast model.
•ICEPOM for the Pan-Arctic and nested Northern Sea Route regions

DATASETS
•Cannon, D. J. Kessler, A. Fujisaki-Manome, J. Wang (2023). Historical simulations of surface and subsurface thermal structure and ice conditions in the Laurentian Great Lakes from 1980-01-01 to 2021-12-31 (NCEI Accession 0276818). NOAA National Centers for Environmental Information. Dataset. https://www.ncei.noaa.gov/archive/accession/0276818.
•Raw and processed data files, analysis, and visualization code for the work described in the Baker et al. manuscript, "Variation in resource competition traits among Microcystis strains is affected by their microbiomes." https://github.com/mLife2023Baker
•Raw and processed data files, analysis, and visualization code for the work described in Dahal et al. 2023 "Impacts of an invasive filter-feeder on bacterial biodiversity are context dependent." https://github.com/nikeshd/LE_SB_feedingExperiments_2019
•Databases used in Yancey et al. 2022 "Metagenomic and Metatranscriptomic Insights into Population Diversity of Microcystis Blooms: Spatial and Temporal Dynamics of mcy Genotypes, Including a Partial Operon That Can Be Abundant and Expressed." https://github.com/ceyancey/mcyGenotypes-databases

WORKSHOPS
•Fish habitat restoration benchmarks: project workshop with Great Lakes fish restoration and management personnel, December 2, 2022.
•Fish habitat restoration benchmarks: follow up workshop, January 27, 2023.
•Unifying Innovations in Forecasting Capabilities Workshop, jointly organized by the UFS, UFS/R2O, and EPIC (Earth Prediction Innovation Center) communities, July 18-22, 2022.

PROPOSALS FOR LEVERAGED FUNDING

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

CIGLR Administration
Gregory Dick, Director, University of Michigan
Sara Hughes, Associate Director, University of Michigan
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
Mike Shriberg, Director for Engagement, University of Michigan (AAR approved 4/17/23)

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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?

We had two senior/key personnel changes during the reporting period.

• Dr. Michael Fraker: Dr. Fraker took a position with Michigan Sea Grant. We submitted AAR 3131926 (approved 3/6/23) to change the PI of Amendment 2 to Dr. Greg Dick, who is now overseeing the work being done on this project.

• Dr. Mike Shriberg: We submitted AAR 3132079 for a permanent organizational structure change to support Dr. Mike Shriberg as CIGLR Director of Engagement. In this role, Dr. Shriberg will provide strategic leadership for CIGLR's Engagement, Career Training, and Outreach (ECO) program, with an emphasis on engaging advocacy groups, policymakers, government, indigenous groups, and underserved populations, to support decision making and align CIGLR's research with the needs of society. The AAR was approved on 4/17/23.

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
Ashley Moerke, Lake Superior 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)
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
Scott Lundgren – Director, NOAA Office of Response and Restoration

Subawardees

Regional Consortium Principal Investigators
Bopi Biddanda, Grand Valley State University
Harvey Bootsma, University of Wisconsin-Milwaukee
Hunter Carrick, Central Michigan University
Rose Cory, University of Michigan
Vincent Denef, University of Michigan

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

36. Have other collaborators or contacts been involved?

Significant NOAA collaborators included:

Philip Chu, NOAA GLERL
Jennifer Day, NOAA GLERL
Ashley Elgin, NOAA GLERL
Reagan Errera, NOAA GLERL
Jesse Feyen, NOAA GLERL
Lauren Fry, NOAA GLERL
Sean Helfrich, NOAA NESDIS STAR
Debbie Lee, NOAA GLERL
Lacey Mason, NOAA GLERL
Steve Pothoven, NOAA GLERL
Mark Rowe, NOAA GLERL
Steve Ruberg, NOAA GLERL
Ed Rutherford, NOAA GLERL
Julie Simmons, NOAA NMFS
Jamese Sims, NOAA NWS
Craig Stow, NOAA GLERL
Dan Titze, NOAA GLERL
Andrea Vander Woude, NOAA GLERL
Hank Vanderploeg, 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:

Invasive species: In an experiment to remove invasive mussels from the lakebed in open water areas of Lake Michigan, we are getting a unique opportunity to understand of how invasive dreissenid mussels have altered the structure and function of the Lake Michigan ecosystem. We expect this project to lead to new insights about the role of mussels in the food web and nutrient cycling by allowing us to address questions that are difficult or impossible using more conventional experimental approaches, such as lab experiments or interpretation of long-term data sets. Further, the removal methods being assessed in this project have the potential to be applied to hotspots of biodiversity and fish production, thereby contributing to the Great Lakes Water Quality Agreement objectives of protecting and restoring the chemical, physical, and biological integrity of Lake Michigan.

Harmful algal blooms: The CIGLR-GLERL HAB monitoring and research program continues to be a benchmark for understanding and predicting HABs and their associated toxins in western Lake Erie. We developed a western Lake Erie Microcystis culture collection that provides a valuable new resource for understanding the environmental and biological factors that influence cyanobacterial bloom dynamics and toxicity. Results to date highlight the genomic diversity among Microcystis strains and associated bacteria in Lake Erie, and their potential impacts on bloom development, toxin production, and toxin degradation. This culture collection significantly increases the availability of environmentally relevant Microcystis strains from temperate North America, which is historically underrepresented in culture collections. We were able to predict microcystin toxin production a week in advance using mcyE gene presence data. This finding has the potential to advance tools to guide management decisions related to safe operations within drinking water intakes, and safe recreational swimming and fishing activities.

Great Lakes Earth System Model: Historical and future changes in the Great Lakes thermal structure remain to be understood due to limited observational measurements, particularly in winter. This project fills this critical knowledge gap by application of the hydrodynamic-ice model. Through the extensive calibration and verification, the model outputs provide a spatiotemporally dense dataset that can fill in the sparse historical observations. In this work, analysis of historical simulations has revealed significant increases in lake temperatures above and below the surface, as well as dramatic losses in both ice cover concentration and thickness over the last 40 years. These changes were especially prevalent in ecologically important bays (e.g. Green Bay, Saginaw Bay), where heating trends were often exaggerated. This work presents one of the most comprehensive analyses of changes in Great Lakes subsurface temperatures to date, providing important context for future climate modelling and coastal management efforts in the region. Furthermore, the hydrodynamic-ice modeling in this project is a core component of the Great Lakes Earth System Model, which inter-connects hydrodynamics, ice, hydrology, lower and higher trophic ecosystem/water quality models. The

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

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. Much of our research during this period focused on the development of tools and products to inform decision making in multiple sectors:

Lake Erie Hypoxia Forecast Transition: This product is used by municipal water treatment facilities to anticipate changes in source water quality, by fisheries managers to plan their surveys, and by state resource managers to help explain changes in nearshore water quality.

Development of a Coupled Hydrodynamic-Wave Model using FVCOM and WAVEWATCH III: Our advanced modeling of Great Lakes waves will advance Great Lakes meteorology though better representation of surface conditions. Other potential users of the models are commercial fishing operators who can predict potential catch according to circulation and temperature; US Navy, business, and nonbusiness ships who plan their sailing routes according to ice and wave conditions; and recreational ice fishers who can find ideal and safe ice conditions.

Advanced modeling to support probabilistic projections of total water levels in Great Lakes coastal areas under climate scenarios: This product will inform water resource managers by providing ranges of future lake level elevations; characteristics of wave, ice, and surge; and longshore sediment transport rates under plausible climate scenarios. This will lead to a substantial improvement over the mangers' current reliance on historic data to evaluate the future risk of their management decisions.

Great Lakes Omics: We were able to predict microcystin toxin production a week in advance using mcyE gene presence data. This finding has the potential to advance tools to guide management decisions related to safe operations within drinking water intakes, and safe recreational swimming and fishing activities.

2022 HABs Monitoring, Forecasting and 'Omics for the Great Lakes: Our research products to aid decision support are used by public water utilities to make decisions about protecting the drinking water supply and by thousands of residents across the region to make choices about recreation. In the longer term, this work is necessary to assess progress towards targets under Annex 4 of the Great Lakes Water Quality Agreement.

Leveraging new satellite assets to improve remote sensing and modeling tools for monitoring and prediction of nearshore water quality in the Great Lakes: The new products we are developing will be able to provide spatial-temporal observations of the Great Lakes nearshore environment, which is the area where primary human interaction occurs. Our products could be important to inform beach closures/notices, or to recreational and commercial fishing activities.

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

CIGLR strives to create a diverse workforce that is skilled in areas related to NOAA's research mission. We represent >60% of NOAA GLERL's scientific workforce, with 55 individuals collocated in the federal laboratory during the reporting period. Through our comprehensive ECO Program, we provided career training opportunities during this period for 14 postdocs, 27 graduate students, and 12 undergraduate students who will become the next generation of NOAA and Great Lakes scientists. CIGLR's career training activities include the Great Lakes Summer Fellowships, Graduate Research Fellowships, Postdoctoral Fellowships, graduate student projects and theses, and project-specific graduate student and postdoc experience. These experiences are supported by a combination of Task IB and University of Michigan cost share funds, in addition to student and postdoc opportunities within Task II research projects.

In Great Lakes Summer Fellows Program, upper lever undergraduate and graduate students participate in an immersive 12-week research laboratory experience, working within diverse teams of experts on substantive research issues while receiving career development mentoring. At the core of our goal to train the next generation of scientists is the collective commitment by CIGLR and GLERL to use these fellowships as an opportunity increase diversity and inclusion in STEM fields. We have a strong recruitment plan to attract a broad range of student applicants in terms of diversity, geography, and STEM disciplines. During this reporting period, we held a competitive selection process and invited 9 students to participate in the summer 2023 program. The selected cohort self-identified as being 22% Asian, 22% Hispanic or Latino/a, 33% White or Caucasian, and 11% Biracial (11% did not answer), and they are affiliated with 8 different universities in 8 states and Puerto Rico. A team of more than 20 mentors from CIGLR, GLERL, NOAA OCM, and the Regional Consortium will work with the fellows on applied research projects that include experiences in laboratory analyses and experiments, field work, scientific instrumentation, modeling, data analysis, and social science. The summer fellowship program is supported by Task 1B and Task II funds.

CIGLR receives Task IB funding, which we augment with cost share funds, to administer a Graduate Research Fellowship Program that provides career training opportunities to master's or doctoral students that are located at one of CIGLR's Regional Consortium universities. In early 2023, we awarded the following Graduate Research Fellowships:

•Elena Litchman, Michigan State University. Dolichospermum in the Great Lakes: a comparison of trait and genetic diversity across Lakes.
•Naomi Levin, University of Michigan. Constraining Evaporative Fluxes on Lake Erie using a Bayesian Isotope Mass Balance Model.
•Rose Cory, University of Michigan. Does hydrogen peroxide in Lake Erie sediments influence the toxicity of Microcystis blooms?
In addition to supporting postdoctoral positions through Task II research projects, CIGLR also administers a competitive Postdoctoral Fellowship Program that is supported by University of Michigan cost share funds. We selected the following Postdoctoral Fellowships for 2023 awards:
•Zack Spica, University of Michigan. Monitoring Lake Ontario Using Distributed Fiber-Optic Sensing.

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

IMPACT *(cont'd)*

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

CIGLR's education activities are implemented within our ECO Program (Engagement, Career Training, Outreach). Our education focus is on undergraduates, graduate students, and postdoctoral fellows in the form of hands-on applied research career training related to NOAA's mission (see question 39). We also engage in public education through our ECO Program by translating and promoting NOAA's research in the Great Lakes (see question 27).

Through CIGLR's competitive ECO award program, students from consortium institutions can apply for funding to incorporate an engagement, career training, or outreach component into their research, thus broadening their educational experience to include society-focused outcomes. We awarded 2 student ECO projects during this reporting period:

¿Empowering Underrepresented Students with GIS – This award supports two students (one graduate, one freshman undergraduate) to create hands-on learning modules for University of Michigan's Earth Camp, to teach high-school students the basics of ArcGIS through mapping exercises that explore Great Lakes environmental issues, with a focus on environmental justice. Earth Camp is a high school outreach program that provides immersive summer programming in Earth sciences to college-bound underrepresented minority students.

¿Building a community-driven model for drinking water news coverage – This award supports a master's project team of 5 students to collaborate with Great Lakes Now, a regional media initiative, to develop an equity-centered, community-driven media model that connects journalists with affected stakeholders. Their project will 1) identify best practices for community-engaged environmental media and solutions journalism, 2) develop an impact assessment toolkit to help media organizations define and achieve their goals, measure their outcomes, and rebuild and refocus newsrooms' commitment to equitable journalism, and 3) convene a community advisory board of regional NGOs, grassroots leaders, and other core stakeholders to support the development and equitable implementation of these tools, which will highlight local water issues and their solutions.

CIGLR PIs and postdocs participated in the following educational activities during the reporting period:

¿Postdoc David Cannon gave a presentation related to climate change in the Great Lakes to undergraduate students participating in the University of Michigan Summer Program in Climate and Space Science Observations (PICASSO). The presentation was designed to teach students how changes in climate can be observed using remote sensing, in-situ measurements, and hydrodynamic models. Cannon, D. (2022) Observing climate change in the Laurentian Great Lakes. Invited Speaker: University of Michigan Summer Program in Climate and Space Science Observation (PICASSO), Ann Arbor, MI. July 8, 2022.

¿PI Dick participated in a Seagull Users livestream in February 2023, which is available on Youtube: https://www.youtube.com/watch?v=y14BVGtJyo4

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

CIGLR's Regional Consortium expands NOAA GLERL's research infrastructure by building strong partnerships with universities across the region who have agreed to share their facilities, vessels, laboratories, and instrumentation with NOAA, while our NGO and business partners help develop applications for NOAA research and bridge science with public interests.

CIGLR's Regional Consortium consists of 10 universities, 2 NGOs, and 3 businesses who partner with NOAA in research and development activities that support NOAA's mission in the Great Lakes. Consortium partners were strategically selected to maximize the scientific expertise, infrastructure resources, and geographic reach available to NOAA in the Great Lakes. The Regional Consortium includes: Central Michigan University, Cornell University, Grand Valley State University, Lake Superior 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, and National Wildlife Federation.

Each of the Regional Consortium members has signed an MOU with the University of Michigan that allows scientists from NOAA, CIGLR, and other Regional Consortium institutions to use their facilities at internal rates. These facilities include:

¿Field stations and laboratories. Partners collectively manage 11 field stations that are located on all 5 Great Lakes. These stations have wet lab space, analytical facilities, housing, classrooms, and experimental mesocosm facilities.

¿Fleet of research vessels. Partners own and operate a fleet of 16 research vessels in all 5 Great Lakes, including several of the largest and most well-equipped vessels available (e.g., Laurentian, Blue Heron, W.G. Jackson).

¿Monitoring instrumentation. Partners own and manage at least 42 buoys, AUVs, ROVs, and gliders that make up a large portion of Great Lakes observing assets, in addition to a wealth of water quality instruments, ADCPs, acoustic telemetry, etc.

¿Specialized engineering and research facilities. All partners have engineering and design labs that specialize in materials design, instrumentation, marine hydrodynamics, and autonomous systems. Partners also operate a suite of highly specialized laboratory facilities, including numerous labs for remote sensing and GIS, genomics and sequencing, bioinformatics, high-performance computing, elemental and isotopic analyses, advanced microscopy, geomicrobiology, sedimentology, and fisheries and aquaculture.

Infrastructure sharing continued to be a very important way to collaborate and conduct research within the Regional Consortium, thus expanding NOAA's mission with efficiency and regional cooperation. During the current reporting period, PI Godwin utilized University of Wisconsin-Milwaukee analytical facilities for sample analyses, which were billed at the internal rate according to the CIGLR consortium MOU. Consortium colleagues from University of Michigan (Denef, Duhaime, Cory, Kharbush) accessed NOAA vessels for

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?

During the reporting period, CIGLR was involved in the following technology transfer activities to benefit research to applications at NOAA and serve the public for a weather ready nation:

¿Runoff Risk v3.0 Assessment. Our rigorous assessment of the newly developed National Water Model-based runoff risk products will improve the likelihood of transition to an operational environment at the NOAA Office of Water Prediction.

¿Lake Erie Hypoxia Forecast Transition. We are supporting the transition of the Lake Erie Hypoxia Forecast to operations with NOAA's National Centers for Coastal Ocean Science (NCCOS). The forecast was previously developed as part of the Coastal Hypoxia Research Program (CHRP, award NA16NOS4780209) and run as an experimental product at GLERL from 2017 to 2021). The model will be run in parallel at GLERL and NCCOS for the 2022 and 2023 summer hypoxia seasons, during which time the performance metrics will be assessed, and technical issues resolved. The experimental hypoxia forecast code was shared with NOAA NCCOS during the reporting period.

¿Development of a Coupled Hydrodynamic-Wave Model using FVCOM and WAVEWATCH III. The findings from this project will inform and contribute to an operational wave forecast from NOAA.

¿Great Lakes Omics. To make our omics data more widely available, especially to stakeholders, we have engaged our partners at the Great Lakes Observing System (GLOS) to integrate some aspects of the GLAMR database into their Seagull platform.

¿Leveraging new satellite assets to improve remote sensing and modeling tools for monitoring and prediction of nearshore water quality in the Great Lakes. We will transfer the shallow water CPA-A to NOAA CoastWatch for experimental/operational deployment. This capability will allow the Great Lakes community to have access to the nearshore water quality products we are developing.

¿2022 Great Lakes Water Level Dashboard Overhaul. We created new web tools for the Great Lakes Water Level Dashboard and the Great Lakes Seasonal Climate Prediction Tool, in preparation for a potential future transition to operations w USACE.

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

Within the Engagement element of our ECO Program, we reach beyond the science community to interact with legislators, resource managers, and other stakeholders and rights holders to identify their information needs, tailor research to meet those needs, and deliver products for decision making.

Our policy engagement activities provide policymakers with information to support decisions, respond to concerns, and understand research needs in the Great Lakes. During this period, we partnered with GLISA to produce the 2022 annual Great Lakes climate summary. The intended audiences for this product are the Great Lakes Water Quality Agreement annexes, the Great Lakes Executive Committee, and policy and decision makers at all levels in the Great Lakes. These are decision making bodies that can impact policy in the United States and Canada.

Our research engagement activities facilitate the co-production of research to develop products that are useful to society, promoting effective decision making and public education. Our work on HABs decision support tools ensures that stakeholders and rights holders have access to real-time information about HABs and research products to aid in decision support. Our products are utilized by thousands of residents across the region to make choices about recreation and by public water utilities to make decisions about protecting the drinking water supply. In the longer term, this work is necessary to assess progress towards targets under Annex 4 of the Great Lakes Water Quality Agreement.

Seed Awards are another opportunity for making a societal impact with our research. These funds provide support to consortium members for response to emergency situations or urgent research needs in the Great Lakes. During the reporting period, we issued a Seed Award to Zack Spica at the University of Michigan, for a project to use existing fiber optic cables in Lake Ontario with Distributed Acoustic Sensing (DAS) to demonstrate the technology's potential for cold season monitoring.

CIGLR also collaborates with NGO, business, and government sectors to help ensure that our science is relevant to society. Our NGO partners are strong advocates for science-based decision making in the Great Lakes; our business partners are leaders in the transition of research to applications in industry; and our government partnerships help to facilitate multi-level, multi-agency, bi-national coordination for the most effective Great Lakes research and management. During the reporting period, we funded 3 summits and working groups that each involve steering committee members and participants from these key sectors. The following summits will be held in late Year 1 and early Year 2:

¿Developing a Conceptual Framework and Vision for Coordinating Great Lakes Connecting Waters Research and Monitoring. Leads: Lake Superior State University, USGS.

¿Discerning the "bricks and mortar" required to implement the societal components of comprehensive Great Lakes restoration.

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 , During the reporting period, $705 (<0.001%) of the total CIGLR award to date ($5.7M) was spent in foreign countries. Foreign expenditures included travel for a workshop and conference in Canada.

CHANGES/PROBLEMS

45. Changes in approach and reasons for change

Nothing to Report

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

Nothing to Report

47. Changes that had a significant impact on expenditures

Nothing to Report

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

Nothing to Report

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

Nothing to Report

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?

In support of NOAA Strategic Goals, CIGLR's research is advancing Great Lakes science and promoting adaptive management through the application of novel techniques to understand environmental problems, prepare communities for environmental change, and develop tools for informed decision making. Through collaborations with NOAA GLERL and our Regional Consortium partners, we are at the forefront of coastal forecasting, high-tech observations, and ecosystem health research to serve the communities that rely on the Great Lakes for human health, safety, and commerce.

During CIGLR's 5-year Cooperative Agreement renewal, we are continuing long-standing research projects to monitor, observe, and predict critical conditions in the Great Lakes, while venturing into new research areas using advanced techniques and technologies. We continue to serve resource managers the tools and information they need to protect public health and wellbeing, by providing real-time observations, remote sensing images, and predictive models that inform drinking water plant operators when source water may be impacted by harmful algal blooms or low oxygen conditions. At the same time, we are leading the way toward using advanced technology to solve environmental problems, by identifying the genetic underpinnings of toxin production by harmful algal blooms, evaluating technologies for invasive mussel removal in open water, and developing new ways for observing and predicting winter-season conditions. We have developed or tested 26 models or technologies for transfer to government operations or commercial application, published 211 scientific papers and reports, and given 403 research presentations since CIGLR's inception in 2017.

We complement our cutting-edge research with programs that engage stakeholders, educate the public, and train the next generation of Great Lakes scientists. As part of the Engagement element of our ECO Program, CIGLR interacts with legislators, resource managers, and other stakeholders to identify their information needs, tailor research to meet those needs, and deliver the products needed for informed decision making. We reach beyond the academic and science community into society, to support research outcomes that make a difference in people's lives. Our engagement activities promote science-based decision making, protect public health and safety, and improve stakeholder and rights holder knowledge and attitudes about NOAA research in the Great Lakes.

We strive to create a diverse workforce that is skilled in areas related to NOAA's research mission through Career Training activities that are part of our comprehensive ECO Program. CIGLR provides career training to students and postdocs who will become the next generation of NOAA and Great Lakes scientists. Through fellowships, thesis/dissertation/professional projects, and research positions, CIGLR has supported 376 students and postdocs since CIGLR began in 2017. Another key career training function of CIGLR is to prepare personnel for federal laboratory employment. Six CIGLR employees were hired as permanent federal staff at NOAA GLERL over the last 6 years.

The Outreach element of the ECO Program 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 more than 8.7 million people have been reached online, through newsletters, and at community events during the past 6 years.

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

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