The Cooperative Institute for Great Lakes Research (CIGLR)

A Non-Competitive Renewal Proposal to the Office of Oceanic and Atmospheric Research, National Oceanic and Atmospheric Administration

1 July 2022 – 30 June 2027

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The Cooperative Institute for Great Lakes Research (CIGLR): A Non-Competitive Renewal Proposal to the Office of Oceanic and Atmospheric Research, National Oceanic and Atmospheric Administration

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Listed by institution in Appendix 7

Budget period	July 1, 2022 through June 30, 2027
Total budget	$53,000,000
Annual budget	$10,600,000

2/28/2022

Gregory J. Dick — Date

I. Abstract

We propose to renew the Cooperative Institute for Great Lakes Research (CIGLR) to accelerate NOAA's mission in the Great Lakes by (1) conducting primary research needed to meet key scientific challenges faced in managing the Laurentian Great Lakes, (2) increasing the impacts of research by fostering engagement with resource managers and decision-makers that help turn science into action, (3) providing cutting-edge career training that prepares a diverse and adaptable workforce of social scientists, natural scientists, engineers and design experts to be the next generation of researchers and practitioners on the Great Lakes, and (4) promoting public literacy about the Great Lakes with a coordinated outreach and communications program across the region.

CIGLR will be composed of a Research Institute and a Regional Consortium. The objective of the Research Institute will be to recruit, train, and retain highly qualified research scientists and scientific staff to work alongside researchers at NOAA's Great Lakes Environmental Research Lab (GLERL). The Research Institute will be complemented by a Regional Consortium that will broaden the intellectual expertise, research capacity, and geographic scope of NOAA's research programs across the Great Lakes region. CIGLR's research will focus on four themes that directly align with NOAA-GLERL research areas:

Theme 1. Observing systems and advanced technology: *monitoring environmental change to help society navigate the Anthropocene.*

Theme 2. Invasive species and food-web ecology: *tracking the dynamics and functioning of Great Lakes ecological communities.*

Theme 3. Hydrometeorological and ecosystem forecasting: *modeling physical and biological processes to help predict the Great Lakes health and future.*

Theme 4. Protection and restoration of resources: *safeguarding habitats, natural capital, and ecosystem services throughout the Great Lakes*

The foci and objectives proposed for each theme address all key topics in NOAA's 20-year Grand Challenges, 5-year Research and Development Plan, and Next Generation Strategic Plan. CIGLR will transition research into practice through the Engagement, Career Training, and Outreach (ECO) Program, thus producing *Great Lakes science for society*. Highlights of our proposal include (i) **exceptional research capacity,** with over 230 PIs and diverse facilities across a Regional Consortium that will support NOAA's mission in the Great Lakes; (ii) **true interdisciplinarity,** with a large group of natural and social scientists and engineering and design experts who will work together to help NOAA-GLERL respond to societal needs; (iii) **bi-national collaboration,** with partner institutions on both sides of the U.S.-Canada border and explicit support of the International Joint Commission; (iv) **major cost-sharing**, with university partners agreeing to highly reduced indirect cost-rates and $3.6 million in cost-sharing over the 5-yr Cooperative Agreement, more than triple the previous commitment; (v) **accelerated transition of R&D**, with meaningful private-sector partnerships with environmental consulting firms, technology development companies, and NGOs who will help us accelerate the transition of scientific research into applications, and augment our mission of engaging the public and policymakers.

II. Results from Prior Research

Since 1989, NOAA has awarded 7 consecutive multi-year Cooperative Agreements (CAs) to the University of Michigan to help NOAA accomplish its mission in the Great Lakes region. Over the course of the current CA (2017-present), CIGLR had a significant impact on Great Lakes science, as demonstrated by overall grant funding, the level of NOAA and academic partnership, research outcomes, and career training activities. With over $24 million in NOAA CA funding and an additional $2.3 million in external funds, CIGLR produced 193 journal articles representing 54% of NOAA-GLERL's peer-reviewed publications. This body of work was cited 6,575 times and mentioned 1,378 times in social media and public news outlets. CIGLR provided career training to more than 250 students and postdocs at 33 institutions and funded $10.3 million in collaborative research and programs that connected NOAA to 22 universities, businesses, and NGOs across the Great Lakes region. During the current CIGLR CA, we continued long-standing research projects to monitor, understand, and predict critical conditions in the Great Lakes, while venturing into new research areas using advanced techniques and technologies. A select subset of CIGLR's research accomplishments is summarized below, organized by major research topic. A comprehensive list of prior research is provided in Appendix 1.

Harmful algal blooms (HABs) *(Themes 1,3).* Our core HAB research program has provided a benchmark for assessing trends of HABs in western Lake Erie and Saginaw Bay and uncovered linkages between nutrient loads from major rivers and HAB responses. We support NOAA-GLERL's development of new models for predicting HAB growth and toxicity, including evaluation, validation, and modification of the Lake Erie HAB Bulletin operated within the NOAA National Ocean Service. Our biophysical modeling of Lake Erie HABs resulted in the development of the 3D HAB Tracker, which was transitioned to operations by the NOAA Center for Operational Oceanographic Products and Services (CO-OPS) in 2020 and is now the NOAA Lake Erie Harmful Algal Bloom Forecast. Experiments answered key questions about the ecology of *Microcystis*, including controls on growth and toxicity, dynamics of buoyant migration, viability in sediments, and impacts of invasive mussel grazing and nutrient excretion.

Hypoxia *(Theme 3).* Scientists from CIGLR and NOAA-GLERL developed an experimental forecast that predicts the location and movement of hypoxic water in the central basin of Lake Erie, providing advance warning of hypoxic upwelling events to public water systems. Our laboratory experiments produced oxygen consumption rates that inform seasonal progression of hypoxia. Our primary research on freshwater manganese cycling, developed in response to stakeholder information needs, advanced understanding of how hypoxia affects the release of manganese and phosphorus from sediments into the water column. Our autonomous nutrient sensors provided unparalleled continuous data linking anoxia to the accelerated release of phosphorus from the sediment to the water.

Lake-effect snow and ice forecasting *(Theme 3).* With NOAA-GLERL and Consortium partners, we developed new tools and improved models to provide NWS forecasters with more accurate lake-effect snow, precipitation, and ice forecast guidance. We reduced forecast model uncertainties through rigorous validation and improvement of model-simulated turbulent heat fluxes, lake ice conditions, lake surface temperature, and heat flux calculation algorithms. We coupled ice-hydrodynamic and atmospheric models to better represent lake surface boundary conditions, which improved forecasts of snow water equivalent downwind of the Great Lakes.

We also produced the first-ever short-term Great Lakes ice forecast guidance for transition to operations in the Great Lakes Operational Forecast System at NOAA CO-OPS.

Flood forecasting (*Theme 3).* We are developing a real-time flood forecast model for the Lake Champlain-Richelieu River system by coupling hydrodynamic, hydrologic, and wind-wave models. Designed to meet requirements for transition to operations at NOAA's National Centers for Environmental Prediction, the model will provide real-time forecasts on a sub-daily basis and incorporate geography to predict inundation, currents, and waves. We are also improving water cycle prediction capabilities of the hydrologic National Water Model (NWM) for the Great Lakes region, which will provide better estimates of total inflows into the Great Lakes and produce more accurate flood forecasts and river/hydrologic conditions in the Great Lakes.

Advanced observing systems (*Theme 1).* In collaboration with partners, we developed new autonomous, near-real-time technologies for monitoring HABs, including moored and mobile Environmental Sample Processors (ESPs) to measure toxins and genomics. The first operational deployment of the 2nd Generation ESP in 2017 provided unprecedented temporal resolution of algal toxin levels to inform decision making. We led the operation of four continuous monitoring water quality buoys in Lake Erie, providing detailed data on water quality conditions, HAB dynamics, and resuspension-driven internal phosphorus cycling in addition to the standard meteorological and physical-chemical constituents. Our application of mobile observing systems includes short-duration AUVs, long-duration buoyancy gliders, and the development of an autonomous mobile ESP to facilitate algal toxin observations at finer spatial scales.

'Omics *(Themes 1-3).* We used 'omics technologies to advance understanding of HAB dynamics and their responses to environmental conditions, and to improve our understanding of rare, endangered, and invasive species. Our research has highlighted tremendous genetic diversity of *Microcystis*, particularly variation in toxin production and predation by invasive mussels, improved the ability to differentiate toxin vs non-toxin producing HABs, and helped identify conditions that trigger toxin production. We detected the genes of toxin-producing organisms even before toxin production, giving promise to early warning and near real-time toxin forecasts. Our use of 'omics methods improved understanding of the effects of invasive mussels on HABs, prompting new research and models to quantify those impacts. We used new environmental molecular methods for detection and quantification of invasive mussels and to track biological responses to physical and chemical changes in the Great Lakes.

Invasive species *(Themes 2-4).* Our support of the NOAA-GLERL long-term research (LTR) program in southern Lake Michigan includes assessing benthic and pelagic food webs and evaluating long-term impacts of various stressors, including invasive species. Our targeted process research and benthic survey data have shown how dreissenid mussels act as the main biotic driver of ecosystem change and critically impact Lake Michigan. We conducted intensive benthos sampling for the 2019 Cooperative Science Monitoring Initiative in Lake Erie and addressed new questions on the effects of HABs and hypoxia on invasive mussels. Our experiments showed that dreissenid mussels can discriminate among food items over short time scales and fine taxonomic resolution, indicating that 'omics approaches are needed to quantify their impacts, and that they may reduce competition for *Microcystis* by removing the smallest cyanobacteria. Finally, we developed ecosystem models to assess effects of Asian carps on food webs of the Great Lakes and the lower Illinois River.

III. Project Description

Overview

The Laurentian Great Lakes are one of the most biologically diverse, economically important, and aesthetically inspiring natural resources on Earth. As the single largest body of freshwater on the planet (22,000 km^3) the Great Lakes contain 20% of the Earth's surface freshwater and 90% of surface freshwater in the United States[1]. Rich in biodiversity and abundant in habitat, the lakes provide ecosystem services like drinking water, recreational and commercial fishing, pollution control, and cultural experiences that hold incredible societal value for more than 35 million residents in the region. The basin collectively supports a gross regional product (GRP) of ~$4.1 trillion USD[2], making it one of the great "blue economies" in the world[3].

But the combination of a dense human population and intense economic activity has led to overexploitation of ecosystems and widespread degradation of habitats throughout the Great Lakes[4]. Today, fewer than half the region's original forest and wetland areas remain. Important fishery resources, such as salmon, lake trout, yellow perch, and walleye, are vulnerable to ecosystem changes and overfishing. The Great Lakes and its watersheds are increasingly under pressure by water extraction, harmful algal bloom intensity and frequency, invasive species introduction and spread, public beach closure frequency, and numerous emerging stressors[4]. The vitality of the Great Lakes, and the prosperity of people who depend on them, will ultimately be determined by our success in learning how to sustainably manage this critical resource.

We propose to renew the Cooperative Institute for Great Lakes Research (CIGLR) to continue to support NOAA's mission to conserve and manage natural resources in the Great Lakes by (1) conducting primary research, (2) increasing the impacts of research by fostering engagement with resource managers and decision-makers that help turn science into action, (3) providing cutting-edge career training that prepares a diverse and adaptable workforce of social scientists, natural scientists, engineers, and landscape designers to be the next generation of researchers and practitioners on the Great Lakes, and (4) promoting public literacy about the Great Lakes with a coordinated outreach program.

As a non-competitive renewal, CIGLR will necessarily retain its research themes and overall organizational structure. However, CIGLR will evolve in several ways in order to respond to its recent review and to take advantage of new opportunities:

Response to External Review

An external review of the research, education, and outreach programs of CIGLR was conducted on April 12-13, 2021. The Science Review Panel rated CIGLR as "Outstanding". In particular, the Review Panel noted that CIGLR's mission is well-aligned with the NOAA mission and that it has been successful in grants acquisition, career training and placement within NOAA, attracting host university cost-share and in-kind support, and outreach and communications. The Panel made two recommendations for the Science Review. First, to generate additional first-authored publications by CIGLR PIs, which was one performance target that was not met. CIGLR recognizes that this goal is critical to enhancing its stature and will increase our focus and investment on publishing first-author papers. The second recommendation was to establish a "venture capital fund" to support work on new directions and emerging issues. In response, we have rebranded our *Rapid Funds* program as *Seed Funds* and broadened it beyond its former focus on emergency response to encompass work on emerging directions and issues. We will

also consider making it available to the CIGLR Research Institute scientists and staff rather than just the Regional Consortium. Review Panel recommendations on the ECO program (increase diversity of staff, focus outreach on health of the ecosystem and across the entire Great Lakes Basin and with environmental justice and cultural issues in mind) and organizational structure are addressed below.

Enhanced Diversity, Equity, and Inclusion

To address the lack of diversity in the Great Lakes science community and NOAA workforce, CIGLR will tackle the issue where it starts – at the very beginning of NOAA-relevant undergraduate programs. We will leverage and link existing programs at universities of the Regional Consortium to facilitate development of an integrated pipeline for recruiting students from K-12, retaining them in undergraduate and graduate programs, and connecting them to CIGLR and NOAA career opportunities. We have also revised our hiring process to follow best practices for inclusive hiring.

New Administrative Structure

Our administration will have a Director, Associate Director, 3 Theme Leads, and a Program Manager. This new administrative structure, approved by NOAA 2/7/22, captures the benefits of both the Theme Lead and Associate Director structures that have been used in the past. Theme Leads effectively coordinate research and manage personnel and projects. An Associate Director will be hired to assist the Director in representing CIGLR at the highest levels, engage the Regional Consortium, and pursue development of strategic research areas and initiatives. See Section VI for details.

Greater investment by host

The University of Michigan has pledged its largest-ever financial commitment as CI host, more than tripling its prior cost-share investment in programs that will help build strong regional partnerships and more active engagement, career training, and outreach for the region. The university's commitment will also provide a substantial increase in administrative support, to ensure our management, financial, grants and contracts, and human resources needs are met as the CI grows.

Expansion of the Regional Consortium

We propose to add Lake Superior State University (LSSU) to the CIGLR Regional Consortium to facilitate collaborations with the new congressionally-mandated US Coast Guard National Center of Expertise for the Great Lakes, which will conduct research on impacts of and responses to oil spills and will be co-located at LSSU and GLERL (see Section III, Project Description).

More interdisciplinary research

Most research in the Great Lakes, including that funded by NOAA, has been led by natural scientists who have focused on understanding the physical and biological processes that underlie environmental problems. While this work has been critically important for understanding how the Great Lakes work, all sustainability problems are ultimately people problems. In planning the new CI, we have taken seriously NOAA's Grand Challenge from its 20-year Research Vision[5] to *"incorporate human behavior into Earth system sciences"* and its 5-year Research and

Development Plan[6] to *"integrate disciplines for a systems perspective."* Our proposal brings together a large group of natural scientists, social scientists, and experts in engineering and design who will work together with NOAA-GLERL to better respond to societal needs by more accurately considering human values and behaviors in the design of research, applications, model outputs, and data products.

Greater focus on co-design

Lasting partnerships are forged only when all who benefit from research work together to define the original questions and prioritize the products needed to solve a problem. The renewed CIGLR will have a substantially expanded set of programs that are designed to foster the co-design of research between NOAA PIs, academic PIs, Great Lakes businesses and industry, NGOs, practitioners, communities, and policymakers. CIGLR will engage in outreach activities that go beyond the one-way of dissemination of information to the public; instead, we will engage stakeholders from the start to finish of research, with continual feedback among researchers and end-users of data and products.

Transitioning research to application

The value of NOAA's research ultimately depends on how well we transition research into mission-driven applications, operational services, and commercialization. With programs like the Research Transition Acceleration Program (RTAP), NOAA continues to accelerate the transition of R&D outputs into operations, applications, commercialization, and other uses for societal benefit (referred to as R2X). CIs, with their close connections to NOAA, help address the agency mission by ensuring that breakthroughs made by CI partners are directly transitioned into the NOAA enterprise. As part of its Regional Consortium, the new CIGLR will forge private partnerships with environmental consulting firms, companies that specialize in commercial application of aquatic instrumentation, as well as numerous industries, manufacturing companies, and NGOs that will help accelerate the transition of scientific research into applications and services for the public. This ultimate goal of supporting the pathway from science to public services is reflected in the CIGLR tagline "Great Lakes Science for Society."

Mission and Goals

NOAA's mission is to *understand and predict changes in climate, weather, oceans, and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resources.* To guide this mission, NOAA commissioned a suite of visioning and planning exercises (e.g., NOAA's 20-year Research Vision[5], Next Generation Strategic Plan[7], and 5-year Research and Development Plan[6]) to identify its most pressing challenges and research needs. NOAA's Chief Scientist (now Administrator) Dr. Richard Spinrad also led a recent evaluation of the CI program, leading to his report titled "*Prospectus for Cooperative Institutes in the 21st Century"* (CI21). A key challenge identified in CI21 was the need for stronger mission alignment between CIs and their respective NOAA labs to maximize the efficiency of NOAA's R&D programs.

NOAA's Great Lakes Environmental Research Laboratory (GLERL) will be the primary sponsor of CIGLR and home of Research Institute personnel. The NOAA-GLERL 2016 strategic research and implementation plans[8,9] which identified four foci that will organize and guide their research in the Great Lakes: (1) Observing systems and advanced technology, (2) Ecosystem dynamics, (3) Integrated physical and ecological modeling and forecasting, and (4) Information services. The mission, goals, and proposed research activities for the new Cooperative Institute

for Great Lakes Research (CIGLR) are directly aligned with NOAA-GLERL's research foci. In addition, all of our research and programmatic activities map onto NOAA's 8 grand challenges in its 20-year Research Vision, 6 research foci in the 5-year Research and Development Plan, and 4 visions in the Next Generation Strategic Plan (Appendix 3).

CIGLR: Mission and goals

CIGLR's mission is to lead research, develop applications and products, and engage with stakeholders to achieve environmental, economic, and social sustainability in the Great Lakes. CIGLR's vision is to be a trusted NOAA Cooperative Institute that brings an expanded research capacity with a multidisciplinary, multisector approach and broad geographic coordination, to inform decision makers and help meet grand sustainability challenges of the Great Lakes. To achieve this mission, all CIGLR activities will revolve around 6 goals:

1. Research institute. CIGLR will operate a productive research institute that complements NOAA-GLERL's workforce with a highly skilled, permanent group of research scientists, technicians, and staff that acts as a fully integrated part of GLERL's scientific enterprise and serves to expand GLERL's research expertise.
2. Regional consortium. CIGLR will expand GLERL's intellectual capacity and research infrastructure by building strong interdisciplinary partnerships with universities, NGOs, and private-sector partners throughout the Great Lakes basin who share similar research and management goals.
3. Science translation. CIGLR will help 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, NGOs, public utilities, and citizen users of data.
4. Engagement. CIGLR will support 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.
5. Career training. CIGLR will foster the development of a diverse, skilled workforce by recruiting and providing career training for undergraduates, graduate students, and postdoctoral fellows who will become the next generation of NOAA and Great Lakes scientists.
6. Outreach. CIGLR will advance Great Lakes environmental literacy by communicating the value, importance, and usefulness of NOAA's research to the general public at local, state, and regional levels.

In the next few sections of the proposal, we provide more details about CIGLR's Research Institute, Regional Consortium, and the research capacity they provide to NOAA.

CIGLR: Research Institute

CIGLR will be, first and foremost, a research institute. As a research institute, CIGLR will complement NOAA-GLERL's workforce with a highly skilled, permanent group of research scientists, technicians, and staff that expands GLERL's research expertise and is fully integrated into GLERL's scientific enterprise (Goal 1). The University of Michigan is ideally suited to serve as the host institution for the Research Institute for several reasons. First, it is a highly

regarded public research institution, ranked the #1 public research university with research expenditures in excess of $1.6 billion. Second, the proximity of the University of Michigan and NOAA-GLERL in Ann Arbor, Michigan facilitates the integration of research functions, as well as communication and collaboration among researchers and staff. Lastly, the University of Michigan and NOAA-GLERL have a 32-year history of research interaction that has led to a highly integrated university-federal workforce that is fully coordinated in its functions.

As host of the next Cooperative Institute, the University of Michigan has made its strongest-ever financial commitment to NOAA, more than tripling its prior cost share commitment (now $3.6M) and pledging additional in-kind support over the 5-year Cooperative Agreement (*Attachment A.* Budget narrative). The host institution will:

1. Enhance NOAA-GLERL's workforce. The University of Michigan will continue to provide NOAA-GLERL with a stable workforce that includes Research Scientists who have appointments in, and salaries partly paid by, the School for Environment and Sustainability and the College of Engineering. The university is prepared to hire new Research Scientists as needed to augment GLERL's workforce (see *Attachment A.* Budget narrative, "Task II Personnel").
2. Support new programs. The University of Michigan will expand its financial support of a suite of programmatic activities that are designed to foster research at NOAA-GLERL and increase interactions with partner institutions. These programs include funds for 3 postdoctoral fellowships per year, 1 graduate fellowship per year, seed funding for new research initiatives and rapid emergency responses to Great Lakes crises, funding for 3 summits and working groups per year that bring multiple stakeholders together to work on Great Lakes problems and co-design research, and funds for education and outreach programs with Regional Consortium members (see Section V. ECO Program; *Attachment A.* Budget narrative, "Cost Share by Host"). Through these activities, CIGLR will provide leadership in themes and directions of Great Lakes Research.
3. Expand its administration. The University of Michigan will substantially increase administrative support for CIGLR, including personnel dedicated to managing the CI's finances, grants and contracts, and human resources, in addition to support for the CIGLR Director and Research Scientists. The university will also provide dedicated physical laboratory and office space for CIGLR . (see *Attachment A.* Budget narrative, "Cost Share by Host" and "In-Kind Support").

CIGLR: Regional Consortium

While the investment by, and long-term commitment from a host institution is vital to the success of a CI, NOAA has also emphasized the need to forge regional partnerships that include consortia of universities, federal agencies, private companies, NGOs, and other organizations that can mutually benefit from the sharing of facilities, equipment, and expertise[10]. As only the second CI to establish a Consortium, the University of Michigan was a pioneer among CIs in developing this broad partnership model to expand GLERL's ability to fulfill NOAA's mission in the Great Lakes. Scientists from the CIGLR Research Institute, Regional Consortium, and NOAA-GLERL have a strong history of collaborative interdisciplinary research on the most pressing issues in the Great Lakes, including climate variability, harmful algal blooms, and protection of ecosystem services. The Regional Consortium will include ten universities and five private-sector partners (Fig. 1), supported by major government agency programs and

organizations, to form a robust partnership that expands NOAA's research capacity, intellectual expertise, and geographic scope across the Great Lakes region.

Universities. Regional Consortium universities currently include Central Michigan University, Cornell University, Grand Valley State University, Michigan State University, The Ohio State University, University of Michigan, University of Minnesota Duluth, University of Windsor, and University of Wisconsin Milwaukee. These academic institutions have been actively involved in research at NOAA-GLERL for many years, thus have expertise that has already proven to be most essential to the success of NOAA-GLERL research programs.

In addition to these current members, **we propose to add Lake Superior State University to the Regional Consortium** to facilitate their major involvement in the new United States Coast Guard (USCG) Great Lakes National Center of Expertise (GLNCOE) for Oil Spill Response and Research. The addition of LSSU to the Regional Consortium now, after the original competition, is necessary and appropriate because the GLNCOE is new (congressionally mandated in 2021), draws on LSSU's unique expertise and geographical location, and will be located at both LSSU and GLERL. LSSU is the only university located at the nexus of three Great Lakes (Superior, Huron, and Michigan) and critical oil pipeline infrastructure including Line 5 in the Mackinac Straits, thus providing strategic advantages of resources and trained personnel in close proximity to Line 5 for rapid response. LSSU is adjacent to the US Coast Guard station in Sault Ste. Marie, the largest sector in Michigan, allowing rapid communication of findings and needs to all partners. It is also adjacent to the US Army Corps of Engineers' Soo Locks in Sault Ste. Marie and major freighter navigational routes, including sites of frequent and recent freighter groundings. LSSU is on the international border, which will help engage Canadian authorities and expertise in response exercises, and near two Native American tribes, the Bay Mills Indian Community and the Sault Tribe of Chippewa Indians.

LSSU's membership in the CIGLR Regional Consortium is also necessitated by their unique, best-in-class expertise, which is critical to meet the goals of GLNCOE set forth by Congress. First, faculty and staff currently serve on oil response strategy teams led by the USCG, including the Straits Area Geographic Response/St. Marys Geographic Response Strategy Committee and Northern Michigan Area Committee. Second, LSSU houses Michigan Sea Grant, which has led initiatives to understand risks associated with oil transportation. Third, LSSU has unique expertise and degree programs in fisheries, wildlife, and robotics engineering. Fourth, experimental aquatic research facilities and environmental chemistry labs at LSSU enable testing impacts of fuel types and recovery techniques with replication and statistical validity. Fifth, existing degree programs (Emergency Management, Fire Science, Criminal Justice-Homeland Security) and facilities at LSSU provide training in incident command, emergency management, and hazardous materials, along with a Regional Training Center that will be expanded to include training for maritime oil spill response. Taken together, these unique features of geography, expertise, and facilities put LSSU in a unique position to support the new NOAA needs defined by the congressionally-mandated GLNCOE. Thus, LSSU will have substantial involvement of GLNCOE through collaboration, participation, and management of the project, justifying its addition to the Regional Consortium.

Private-sector partners. NOAA has repeatedly emphasized that partnerships with the private sector are important for maximizing the impact of its R&D programs[10]. Not only are private organizations key to developing applications for NOAA-funded research, industries, NGO's, and citizen groups are also key to engaging policymakers and resource managers in ways that bridge science with public interests. CIGLR's Regional Consortium will continue to include 5 private-sector partners with significant expertise to help fulfill CIGLR's science translation goal:

- The Nature Conservancy (TNC) is one of the world's largest and most respected charitable organizations. TNC's mission is to *"conserve the lands and waters on which all life depends."* One of their most significant conservation initiatives is the TNC Laurentian Great Lakes Project, which works in 8 states and Canada to develop practical, outcome-based solutions to protect water quality and ensure the health of the region's watersheds and coasts. TNC has provided a letter of support for this proposal (Appendix 5) in which they have expressed their desire to partner with CIGLR in research activities that involve conservation and protection of the Great Lakes. In addition, TNC has also expressed a desire to partner in our ECO program (Section V) to expand CIGLR's engagement, communication, and outreach efforts to reach the broader audience associated with TNC around the Great Lakes.
- The National Wildlife Federation (NWF) is the United States' largest private, nonprofit conservation education and advocacy organization, with over 6 million members and supporters, and 51 state and territorial affiliated organizations. Since 1982, NWF's Great Lakes Regional Center has been a leader in protecting the Great Lakes for wildlife and humans that depend on this invaluable resource. One of NWF's strengths lies in advocating for conservation of habitat and wildlife throughout the Great Lakes region. They have an unparalleled number of agreements and interactions with other NGOs and business leaders throughout the Great Lakes who share mutual interests in conservation. In addition, NWF runs the National Advocacy Center that is one of the best at engaging policymakers from state to federal levels. NWF has provided a letter of support (Appendix 5) in which they have agreed to partner with CIGLR to help us expand our efforts in policy engagement.
- LimnoTech is a leading water sciences and environmental engineering consulting firm. Founded in 1975, the company is headquartered in Ann Arbor, Michigan, with regional offices in Washington, DC, the Minneapolis-St. Paul region, and the Los Angeles region, with other personnel in Austin, TX, and Greensboro, NC. LimnoTech plays a key role in Great Lakes observing and monitoring systems, having led the Great Lakes Observing System Enterprise Architecture Design[11], which was a comprehensive, interdisciplinary process conducted with NOAA-GLERL to recommend specific actions and investments for the next 5 years to achieve an integrated observing system for the Great Lakes. LimnoTech also manages a set of observing systems (16 water quality monitoring stations in western Lake Erie) that are an integral part of the Great Lakes Observing Systems (GLOS), and which help characterize source water for intakes. LimnoTech has provided a letter of support for this proposal (Appendix 5) in which they have agreed to partner with CIGLR to coordinate and expand observing systems – particularly to assist operators of public utilities such as water treatment plant operators in the Great Lakes.
- Fondriest Environmental, Inc. is a leading distributor and integrator of equipment for natural resource professionals, and a certified repair center for a variety of leading sensor, platform, and telemetry equipment. Located in the lower Great Lakes and Ohio River Valley, they

provide integrated solutions for sensor, platform, and equipment needs and work closely with NexSens Technology, a company that specializes in the design and manufacture of real-time environmental measurement and monitoring systems. Fondriest Environmental has provided a letter of support for this proposal (Appendix 5) and agreed to partner with CIGLR by making available engineers, computer programmers, and other staff to support CIGLR's monitoring efforts in the Great Lakes; build and deliver instrumented monitoring stations that help NOAA and CIGLR accomplish research goals; and offer ongoing support and repair services for NOAA-GLERL and CIGLR's existing fleet of monitoring instrumentation and systems deployed throughout the Great Lakes.

- Great Lakes Environmental Center, Inc. GLEC is an environmental consulting firm that has performed laboratory and field investigations concerned with the protection and restoration of the Great Lakes under contracts to the U.S. EPA, Michigan Department of Environmental Quality (MDEQ), Michigan Department of Environment, Great Lakes, and Energy (EGLE), and the U.S. Army Corps of Engineers. GLEC headquarters in Traverse City, MI has labs for aquatic toxicology, environmental chemistry, and taxonomy. Additional toxicology labs operate at GLEC's Columbus, OH facility, with satellite offices in Farmington Hills, MI and Eau Claire and River Falls, WI. GLEC toxicologists, ecologists, environmental engineers, and biologists have played a key role in establishing ecologically based national, state, and site-specific water quality standards and criteria. GLEC has provided a letter of support for this proposal (Appendix 5), agreeing to partner with CIGLR by making staff available to support CIGLR's monitoring efforts in the Great Lakes, and to assist with toxicology studies, when needed, to fill any gaps in NOAA-GLERL's expertise.

All Regional Consortium members have signed Memoranda of Understanding (MOUs) with the University of Michigan (Appendix 4) that guarantee NOAA a uniformly low cost of collaborating with Regional Consortium members across all 5 Great Lakes and ensure access to the most productive and strategically located research vessels and research labs in the basin.

The Regional Consortium MOUs define the in-kind support provided by member institutions and organizations, including:

1. Reduced IDC. Regional Consortium members will reduce indirect cost rates to 26% for all NOAA projects sub-awarded through CIGLR and reduce indirect costs rates to 10% for all postdoctoral and graduate fellowships funded through CIGLR's programmatic activities. Two modifications were required for members to comply with their university policy. Cornell University will not be awarded projects that do not meet Cornell's definition of off-campus work, and any Postdoctoral Fellowships received by Cornell will charge a combination of salary plus benefits and/or IDC according to Cornell Policy and providing that the total amount does not exceed the maximum amount of funding for the given year's total Fellowship award. The University of Minnesota, Duluth will review larger projects on a case-by-case basis for approval of the reduced IDC rate.
2. Research Infrastructure. Regional Consortium members will grant full access by NOAA scientists, CI scientists, and other Regional Consortium members to their Great Lakes research vessels and laboratory facilities at their discounted in-house cost.

In exchange for their intellectual expertise, access to research infrastructure, and in-kind support of research and programs, the University of Michigan will provide Regional Consortium members with a suite of programs designed to foster interactions with the CIGLR Research Institute and NOAA-GLERL. These programs include competitive postdoctoral and graduate student fellowships, funding for working groups and summits, seed funding to respond to emerging issues in the Great Lakes, and supplemental funding to coordinate education and outreach activities (Section V. ECO program).

Figure 1. The Cooperative Institute for Great Lakes Research (CIGLR) will be composed of a Research Institute hosted at the University of Michigan, complemented by a Regional Consortium of an additional 9 universities and 5 private-sector partners that span all 5 Great Lakes.

Supporting Initiatives and NOAA Programs. A wealth of NOAA programs, government centers, and national and international commissions serve various functions in research, policy engagement, or public outreach and communications in the Great Lakes. Some of the most important and influential initiatives and programs in the Great Lakes have agreed to support CIGLR and work with us to leverage expertise, funding, and programs to the mutual benefit of all programs that serve the Great Lakes. These include:

- Great Lakes Observing System (GLOS). GLOS is one of 11 Regional Associations of the Integrated Ocean Observing System (IOOS), working to enhance the ability to collect, deliver, and use ocean and Great Lakes information. IOOS is a partnership among federal, regional, academic, and private sector parties that work to provide data for tools and forecasts to improve safety, enhance the economy, and protect our environment. We deliberately selected Regional Consortium members who are also partners with GLOS to ensure that the research programs of CIGLR and GLOS are well integrated and mutually beneficial. In fact, numerous projects proposed in Section IV Research Themes were developed in consultation with GLOS partners and the Executive Director of GLOS, Kelli Paige. Because of the explicit integration of GLOS into CIGLR's research and programs, Ms. Paige has provided a strong letter of support and endorsement for our proposal (Appendix 5) and has committed to continue to work together with the new CI to accomplish our joint goals. Our coordination with GLOS will be facilitated by the collocation of GLOS administrative offices with CIGLR at NOAA-GLERL, where Ms. Paige and CIGLR's Director (Greg Dick) will meet regularly once administrators are back in person.
- NOAA National Estuarine Research Reserves (NERRS). NERRS is a network of 28 coastal sites designated to protect and study estuarine systems. Two of these reserves are in the Great Lakes (Old Woman Creek, and the Lake Superior Reserve). The NERRS Science Collaborative, which coordinates funding opportunities and supports user-driven collaborative research and transfer activities that address coastal management needs, is hosted at the University of Michigan. Director Dr. Jennifer Read, who is co-PI on this proposal, will help coordinate NERRS activities with related CIGLR activities to leverage research, education, and outreach in ways that maximize NOAA's impact in the Great Lakes estuarine reserve system.
- NOAA National Marine Sanctuaries. Ellen Brody, the Regional Coordinator of NOAA's National Marine Sanctuaries in the Great Lakes – Thunder Bay and the new Wisconsin Shipwreck Coast – has provided a letter of support agreeing to partner with CIGLR and GLERL on research activities (Appendix 5), working together to characterize and monitor sanctuary resources, and promoting education programs that are mutually beneficial. Several activities have been proposed (Section IV. Research Themes) to complement the goals and ongoing programs in these sanctuaries.
- USGS Great Lakes Science Center. The USGS-GLSC exists to meet the Nation's need for scientific information for restoring, enhancing, managing, and protecting living resources and their habitats in the Great Lakes basin ecosystem. The Center is headquartered in Ann Arbor, MI, but supports 25 Principal Investigators at 7 locations that span the entire Great Lakes basin. In addition, USGS-GLSC owns and operates 5 state-of-the-art research vessels and 3 major aquatic laboratories. Russ Strach, Director of USGS-GLSC has provided a letter of support for this renewal proposal, emphasizing that the renewal of CIGLR will facilitate valuable program-scale collaborations for the benefit of USGS, NOAA, regional research and management partners, and the general public.
- Great Lakes Commission (GLC). The GLC is an interstate compact agency that promotes the integrated development, use and conservation of the water and related natural resources of the Great Lakes basin. Its members include the 8 Great Lakes states with associate member status for the Canadian provinces of Ontario and Québec. Each jurisdiction appoints a

delegation of 3 to 5 members representing senior agency officials, legislators and/or appointees of the governor or premier. GLC's specialty is policy and advocacy, including their annual Great Lakes day on Capitol Hill in Washington D.C. GLC has provided a letter of support (Appendix 5) in which they have agreed to leverage their connections and expertise to help CIGLR be successful in its engagement with policymakers.

- International Joint Commission (IJC). The IJC is an independent binational organization established by the United States and Canada under the Boundary Waters Treaty of 1909. It assists in the protection of the transboundary environment, including the implementation of the Great Lakes Water Quality Agreement and the improvement of air quality, and it alerts the governments to emerging issues along the boundary that may give rise to bilateral disputes. The IJC is particularly enthusiastic about CIGLR's work because our Regional Consortium includes both U.S. and Canadian institutions who have agreed to work together. IJC has provided a letter of support (Appendix 5) stating that CIGLR plays an important role in conducting science to produce data, models, and forecasts that are valuable to the IJC, and that they will participate in our programs where possible.

CIGLR: Research Capacity

The interdisciplinary focus of the next CI is also represented by the list of co-PIs from University of Michigan, which includes 3 aquatic ecologists (Dick, Denef, Johengen), an environmental chemist (Ault), an engineer (Kerkez), an atmospheric scientist (Jablonowski), an expert in coastal planning and management (Norton), a toxicologist (Svoboda), and 3 social scientists from environmental policy (Hughes), environmental history (Read), and climate adaptation (Lemos). These 10 individuals are all internationally recognized leaders in their respective disciplines, and have led or participated in major national and international initiatives focused on environmental sustainability. This also includes the directors of all NOAA-related programs on the University of Michigan campus (CIGLR – Dick; Sea Grant – Johengen; GLISA – Lemos, and NERRS – Read). These individuals have committed to coordinate and leverage activities and research programs at the University of Michigan to further advance NOAA's overall research mission in the Great Lakes.

The host institution also supports 6 Research Scientists who have partial research faculty appointments in the School for Environment and Sustainability and in the College of Engineering. These 6 PIs have more than a century of experience working at NOAA-GLERL in support of research on the Great Lakes, with expertise in hydrodynamic modeling (Beletsky), climate and weather modeling (Fujisaki-Manome), bio-physical modeling (Fraker), physical limnology (Johengen), 'omics (Chaganti), and harmful algal blooms and biogeochemistry (Johengen, Godwin).

In addition to the host institution, this proposal includes 10 co-PIs representing each academic institution within our Regional Consortium. These 10 co-PIs have hundreds of years of collective experience in research and management of the Great Lakes and represent some of the most prominent and influential scientists in the region. They also represent universities who have worked with scientists at NOAA-GLERL most frequently and many are directors of prolific water centers and research institutes on the Great Lakes. Collectively, the Regional Consortium offers NOAA-GLERL a wealth of research infrastructure (Appendix 2), including:

- Field stations and laboratories. Regional Consortium members collectively manage 11 field stations that are located on all 5 Great Lakes. These stations have wetlab space, analytical facilities, housing for researchers and students, classrooms for teaching and hosting of seminars, aquaculture facilities and world-class mesocosm facilities for experiments.
- Fleet of research vessels. Regional Consortium members 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., *Blue Heron*, *Laurentian*, *W.G. Jackson*).
- Monitoring instrumentation. Regional Consortium members own and manage 42 buoys, AUVs, ROVs, and gliders that already form a large portion of the Great Lakes Observing System (GLOS). The University of Windsor, which has joined the Regional Consortium as a Canadian partner, received a $15.9 million grant from the Canadian Foundation for Innovation (CFI) to form the Real-time Aquatic Ecosystem Observation Network (RAEON; raeon.org), composed of real-time sensory arrays, 4 Slocum Gliders, and *in situ* instrument pools (e.g., water quality instruments, acoustic telemetry, etc.). RAEON is part of a pending proposal to create a Canadian freshwater observation network *Global Water Futures Observatories* (CFI-Major Science Initiatives, 10 universities $41.2 million) and to expand into the watershed of the Great Lakes through a University of Guelph led CFI proposal called *Freshwater Ecosystem Assessment and Management (FEAM) network* ($14.9 million). This infrastructure and technical expertise is available to the Great Lakes community and has been leveraged for bi-national funding and research through the CIGLR partnership.
- Specialized engineering and research facilities. Regional Consortium universities have engineering and design labs that specialize in materials design (plastics, metals, glass), development of instrumentation, marine hydrodynamics, and perpetual robotics for autonomous navigation and mapping systems. Regional Consortium members also operate a suite of highly specialized laboratory facilities that further expand NOAA's capabilities in the Great Lakes, including numerous labs for remote sensing and GIS, genomics and sequencing, bioinformatics, high-performance computing, marine hydrodynamics, elemental and isotopic analyses, advanced microscopy, sedimentology, and fisheries and aquaculture.

In addition to the research infrastructure being offered by the Regional Consortium, we offer NOAA-GLERL a breadth of topical and disciplinary expertise that includes:

- An interdisciplinary group of 164 natural scientists, 42 social scientists, and 39 experts in engineering and design who have a history of working on issues related to sustainability in the Great Lakes.
- Substantial depth and expertise in every NOAA theme. Regional Consortium PIs represent some of the most influential researchers in every theme that NOAA emphasized in the FFO for this CI (Appendix 7).
- A suite of Engagement, Career Training/Education, and Outreach (ECO) Programs. Regional Consortium universities all have programs with staff whose primary job involves engagement or public outreach and education in the Great Lakes.
- The 10 Regional Consortium universities collectively offer dozens of M.S. and Ph.D. programs that are relevant to NOAA's goals and the training of the next generation of Great Lakes scientists. These include degrees in the biological sciences (e.g., ecology, genomics),

physical sciences (e.g., limnology and oceanography, atmospheric science, geology), social sciences (e.g., water policy, human behavior), engineering (e.g., naval architecture and marine engineering), interdisciplinary degrees that train students in sustainability (e.g., sustainable systems, policy and planning), and natural resource management (e.g., fisheries & wildlife, conservation biology). In addition, Regional Consortium universities have relevant undergraduate programs that serve as pipelines to graduate programs as well as CIGLR and NOAA programs. This includes Lake Superior State's dedicated undergraduate programs in Fisheries and Wildlife Management, Environmental Science, and Robotics Engineering.

- A strong commitment to diversity, inclusion, and equity. All Regional Consortium universities administer programs that are specifically designed to foster and maintain diversity in the workplace, including (1) increased opportunities for training and preparation of ethnic and socio-economic minority groups in the STEM topics (science, technology, engineering and math), (2) increased representation and retention of individuals from traditionally under-represented groups such as ethnic minorities, women, the LBGTQ community, and veterans, and (3) enhanced opportunities for those who are disabled or have special needs.

We plan to leverage this intellectual capacity, diverse workforce, and coordinated set of engagement, career training, and outreach programs to benefit NOAA's mission across all of the Great Lakes. A summary of the research infrastructure and intellectual capacity of Regional Consortium universities is given in Appendix 2

IV. Research Themes

Administrative Task IA Activities

The primary role of administration is to support research carried out in CIGLR's Research Institute and Regional Consortium, and to support the Engagement, Career training, and Outreach (ECO) Program. Two of the most important administrative tasks will be facilitating financial elements of the Regional Consortium and developing, implementing, and coordinating multi-university research programs. The other administrative activities that are important to the CI include interacting with PIs, communicating with NOAA research and administrative staff, and providing administrative support for CIGLR postdoctoral fellows, student fellows, visiting scientists, and research staff. The administrative and organizational structure of the CI are further detailed in the Business Plan (Section VI).

Non-administrative Task IB Activities

Task IB activities will include career training and outreach activities that align with the missions of CIGLR and NOAA-GLERL. These include:

- Graduate Research Fellowships. CIGLR will administer 2 graduate fellowships per year to students affiliated with Regional Consortium universities. Graduate fellows must be performing research in the Great Lakes on topics related to NOAA-GLERL's mission and be working in collaboration with both a Regional Consortium PI and a NOAA-GLERL or CIGLR scientist. Funds may be used for tuition, stipends, research materials/supplies, or travel. Regional Consortium members have agreed to a reduced IDC rate of 10% on graduate fellowships.

- Great Lakes Summer Fellows Program. CIGLR will administer NOAA funding for at least 6 summer internships per year to upper-level undergraduate and graduate students to work with CIGLR and NOAA-GLERL scientists on ongoing Great Lakes research projects.

- Visiting Scientist Program. CIGLR will facilitate and coordinate opportunities for Great Lakes academic scientists to visit NOAA-GLERL and CIGLR to conduct collaborative research, take advantage of NOAA facilities and resources, and advance research activities with NOAA PIs. Such visits could range from longer-term sabbatical leaves in residence at NOAA-GLERL to shorter-term programs that allow academic scientists to have office space at CIGLR and/or NOAA-GLERL, and local accommodations for a period of 1-2 weeks.

- GLERL-CIGLR Seminar Series. As part of its ECO Program (Section V), CIGLR will co-sponsor and coordinate a joint GLERL-CIGLR Seminar Series. This series will bring in internationally-recognized researchers to talk about topics that are pertinent to both GLERL and members of our Regional Consortium. These events will facilitate collaborations between researchers, provide an educational opportunity for NOAA and university scientists, and serve as an outreach forum for stakeholders and the general public to attend.

In addition to the above activities, CIGLR will provide administrative support for our internally-funded programs, which include: (1) annual postdoctoral fellowships, (2) summits and working groups that convene experts from Federal and state agencies, academia, NGOs, and private businesses to co-design Great Lakes research programs, (3) seed grants that provide funds for research on emerging issues and responses to emergencies in the Great Lakes region, and (4) education and outreach funds to promote the societal benefits of NOAA research in the Great

Lakes. These programs will not be paid from Task I funding but rather from cost-share funding from the University of Michigan. These programs are outlined in *Section V. ECO Program* of the proposal.

Research Programs. Tasks II and III Activities

Here we propose a collection of research activities designed to help NOAA-GLERL execute its strategic research plan[8,9] and to help CIGLR accomplish its mission to lead research, develop applications and products, and engage with stakeholders in the Great Lakes. While details of the specific projects will depend on funding opportunities, this summary is presented to show the broad research capacity and potential that our Research Institute and Regional Consortium bring to NOAA's mission. We will work with PIs at NOAA-GLERL to prioritize annual projects and will apply for external funding to support the additional ideas proposed here.

Research activities are organized by the 4 research themes that were identified in the original NOAA FFO that called for a new Great Lakes CI: (1) Observing Systems and Advanced Technology, (2) Invasive Species and Food-web Ecology, (3) Hydrometeorological and Ecosystem Forecasting, (4) Protection and Restoration of Resources. Note that in 2017 we altered the name of Theme 3 from that in the FFO (which focused solely on invasive species) because NOAA-GLERL has a strong history of research in food-web dynamics and other aspects of ecological forecasting that extend beyond invasive species. In 2017 we also re-ordered the sequence of themes to emphasize that data collected from observational systems (Theme 1) and ecological observations (Theme 2) are then used for forecasting (Theme 3), which facilitates the protection of natural resources for the good of society (Theme 4). Finally, we have also highlighted a set of research foci that cut across multiple themes.

Within each of the 4 research themes, subdivisions show 'foci' representing broad areas of research that are either essential to GLERL's core research programs or that represent new areas that would substantially expand NOAA's impact on our understanding and management of the Great Lakes. Each focal area is populated by a suite of objectives. Project-level details will be determined by available funding. Appendix 3 shows how the research foci map onto NOAA's 20-year Research Vision[5], Next Generation Strategic Plan[7], 5-year Research and Development Plan[6], and research gaps identified in NOAA's 2017 FFO. We have not explicitly mapped projects onto Research Themes outlined in GLERL's Strategic Plan[8] because they overlap in entirety (our Theme 1 = GLERL (1) Observing systems and advanced technology + (4) Information systems, our Theme 2 = GLERL (2) Ecosystem dynamics, Our Theme 3 = GLERL (3) Integrated physical and ecological modeling and forecasting). Note, however, the Theme 4 of our proposal (Protection and Restoration of Resources) is complementary to NOAA's goals and expands their capabilities with more integrated natural and social science.

Theme 1. Observing Systems and Advanced Technology
Monitoring environmental change to help society navigate the Anthropocene

The Great Lakes are used by a diverse group of stakeholders whose health, economic well-being, and quality of life are fundamentally dependent on the use, protection, and management of the region's water related natural resources. Making scientifically sound decisions on how to use and manage these natural resources requires well-integrated observing systems that monitor key aspects of the Great Lake environment at high spatial and temporal resolution. Comprehensive, well-integrated Earth observing systems are also needed to quantify natural levels of variation,

identify natural and human-induced disturbances, provide the data needed to develop climate, weather, and ecosystem forecasts, and to prepare the baselines needed to assess the success of management decisions. CIGLR will support NOAA's short- and long-term research objectives in the Great Lakes during the 2022-2027 renewal cooperative agreement by continuing core research efforts directed at the development and operation of advanced observing technologies, while exploring the development of new data products for the scientific community and the public.

Focus 1a. In Situ Fixed Mooring Systems

Objective 1a.1: Implement a regionally distributed network of real time observing systems (core)

Potential PIs: CIGLR – Johengen, Miller, Read (UM), Steinman (GVSU), Bootsma (UWM), Austin (UMD), Verhamme (LimnoTech); GLERL – Ruberg; Partners – Paige (GLOS),

Over the past decade, CIGLR has partnered with the IOOS Great Lakes Observing System (GLOS) to develop, implement, and coordinate the Great Lakes Nearshore Observing Network that serves multiple federal and academic partners. During this renewal, CIGLR will continue operation of the University of Michigan-established GLOS observing assets (buoys, gliders, vessel of opportunity) and continue to align our activities with priorities identified in GLOS's new Smart Lake and Lake Bed 2030 Initiatives. Priority data observations and products will continue to address key stakeholder needs in the broad focus areas of Climate Adaptation, Ecosystem Health, Maritime Operations, and Public Health and Water Security. A core activity within this objective is continued operation of an integrated array of nearshore observing buoys that consist of a minimum standard configuration with cellular communications, wind speed and direction, air temperature, and relative humidity. As possible, additional instrumentation may include solar radiation, barometric pressure, precipitation, thermistor string, YSI sondes, a current profiler, and wave sensor. The observing network also supports mobile platforms, including gliders and AUVs that provide detailed three-dimensional observations of thermal structure, as well as surveys focused on harmful algal blooms, invasive species, and coastal nutrient inputs. These broader lake-wide surveys are being done in collaboration with other federal partners including the EPA Great Lakes National Program Office (GLNPO) and the USGS, as part of the Coordinated Science and Monitoring Initiative. Data from observing systems are made available through the GLOS Data Portal to help GLOS meet its mission for the Great Lakes region as a whole and will be made compliant with the new Seagull data management platform. The operation of these observing systems is sufficiently flexible such that the individual activities can be tailored to local user needs.

Objective 1a.2: Advanced technologies to measure toxins and contaminants (core)

Potential PIs: CIGLR – Johengen, Godwin, Dick (UM); GLERL – Ruberg, Errera, Vander Woude; Partners – Scholin, Ussler (MBARI), Goodwin (NOAA AOML), Doucette (NOAA-NOS-NCCOS), Ates (LSU)

CIGLR will continue to use the intellectual and infrastructure resources offered by our Regional Consortium to develop and apply state of the art technologies on fixed mooring platforms that provide information to managers and the public on a near-real-time basis. The primary focus of this objective is to support the development and deployment of multiple Environmental Sample Processors (ESPs) for detecting harmful algal bloom species and associated toxins in real time.

CIGLR is partnering with GLERL, Louisiana State University, Monterey Bay Aquarium Research Institute, NOAA's National Centers for Coastal Ocean Science, and NOAA's Atlantic Oceanographic and Meteorological Laboratory on a project funded by NOS-NCCOS to integrate the 3rd Generation (3G) Environmental Sample Processor (ESP) into an uncrewed surface vehicle platform capable of sampling at multiple depths within the water column. That platform would be operated in coordination with an uncrewed aircraft system (UAS) using hyperspectral cameras to discriminate cHABs nearshore. Future efforts will be directed toward the development of a multiplex microcystin/saxitoxin assay for the ESP to address other known toxins that are being produced by local HABs. CIGLR will support both the laboratory and fieldwork associated with the preparation and deployment of the ESP in collaboration with Dr. Reagan Errera (NOAA-GLERL), and with Dr. Greg Doucette (NOAA-CCEHBR) to develop the specific protocols for the microcystin/saxitoxin multiplex ELISA assay.

Objective 1a.3: Develop a continuous dissolved oxygen monitoring network within Lake Erie to support Great Lakes Water Quality Agreement objectives (core)

Potential PIs: CIGLR – Johengen, Godwin, Fraker (UM); GLERL – Ruberg, Stow, Rowe

Seasonal hypolimnetic hypoxia is a long-standing phenomenon in Lake Erie. In addition to habitat impacts of the deeper waters of Lake Erie's central basin, upwelling events periodically push hypoxic water into shallow nearshore areas, causing fish kills, problems at drinking water intakes, and odor problems in nearby communities. The spatial and temporal extent of hypoxia is greater than previously recognized, and short-term hypoxic events may occur regularly in some nearshore areas. To combat this recurring problem the updated 2012 Great Lakes Water Quality Agreement included the lake ecosystem objective: "minimize the extent of hypoxic zones in the Waters of the Great Lakes associated with excessive phosphorus loading, with particular emphasis on Lake Erie". In response, updated phosphorus load targets were promulgated in 2017 to reduce hypoxia in Lake Erie's central basin and the goal of attaining an average DO concentration of > 2 mg/L in the hypolimnion during the hypoxic season was established.

To monitor the spatial and temporal coverage of hypoxia, develop appropriate indicators, and measure the response of hypoxia to changing loads, it is necessary to deploy a monitoring network adequate to quantify the duration, spatial extent, and thickness of the hypoxic layer. CIGLR will work with NOAA-GLERL to support the development of a mooring network, consisting of 10 moorings throughout the central basin of Lake Erie to provide temperature and dissolved oxygen data in Lake Erie to assess hypolimnetic dissolved oxygen status and trends. Each mooring will be outfitted with 6-8 vertically distributed temperature and dissolved oxygen sensors to monitor changes throughout the water column at 20-minute intervals from May through September. Additional spatial monitoring of thermal structure and dissolved oxygen concentrations throughout the water column will be provided from Slocum glider missions. The data from these moorings and gliders will also support further development and testing of GLERL's Lake Erie dissolved oxygen model, a tool developed to provide an early warning to drinking water intakes when an encounter with hypoxic water from the hypolimnion is imminent.

Objective 1a.4: Develop advanced warning systems: Public applications of observing systems (core)

Potential PIs: CIGLR – Johengen, Miller (UM); GLERL – Ruberg

Over the past 5 years, CIGLR has supported the development of the Great Lakes Synthesis, Observations and Response System (SOAR) program at NOAA-GLERL to coordinate regional coastal observations that support regional priorities, including Great Lakes restoration. The observing systems data collated and distributed by SOAR provides real-time information to help public utility managers maintain high quality drinking water and informs the public on current water quality conditions. Furthermore, observations are used to develop decision support tools that provide warnings to regional managers and support adaptive management decisions on water quality, harmful algal blooms (HABs), and hypoxia in locations like Maumee Bay, Saginaw Bay, Muskegon Lake Area of Concern (AOC), Lake Michigan, and Lake Erie. Future efforts will expand the advanced warning systems offered by SOAR, and the number of data end-users.

Within the SOAR program, CIGLR's research efforts will be directed to (1) provide real-time, quality-assured, nutrient and optical data for the web-based decision support system disseminated through GLERL and GLOS web portals, (2) provide data for calibration and validation of satellite remote sensing estimates used in operational HAB forecast products, (3) develop necessary lake ecosystem data to assess the effectiveness of Great Lakes Water Quality Agreement-proposed watershed remedial actions, and (4) develop predictive models to improve decisions by water intake and beach managers to protect public health. We will continue field collection of ground-truth samples to validate and refine remotely sensed determinations of sediment plumes and nuisance algal blooms, and conduct profiles to measure inherent optical properties using the Satlantic hyperspectral profiler, the Satlantic hand-held hyperspectral imager, and WETLabs ac-s and BB9 absorption and backscatter instruments to aid in algorithm development and validation of remote sensing estimations of color producing agents.

A primary contribution of CIGLR within this program has been on the advancement of in situ nutrient observations performed at hourly intervals. We have developed a network of four water quality monitoring buoys in western Lake Erie that include a SeaBird Coastal SUNA spectrophotometric nitrate sensor and HydroCycle P wet chemistry phosphate sensor. These technologies have provided unprecedented temporal scales of in-lake nutrient monitoring that improve our understanding of inter-annual and seasonal patterns in HABs development. The highly resolved data improves our ability to track how the ecosystem is responding to the proposed nutrient loading guidelines developed under the GLWQA. We plan to work with partners to expand the application of these technologies into additional regional monitoring programs and watersheds for more accurate tributary loading estimations. All monitoring data will be transmitted in real-time via GLERL's Real Time Coastal Observation Network (ReCON) and disseminated publicly through GLERL and GLOS web portals.

Objective 1a.5: Operate long-term, year-round, whole water column temperature strings to assess climate impacts on lake thermodynamics (core)

Potential PIs: CIGLR – Johengen, Miller, Gronewold (UM); GLERL – Ruberg, Titze, Wang, Lofgren

While the response of lake surface water temperatures to climate change is well documented, our understanding of how water temperatures are responding at depth is limited due to very few detailed long-term subsurface observations. Recent analysis of three decades of high frequency subsurface water temperature data from Lake Michigan revealed that deep water temperatures are rising in the winter, fall overturn is being delayed, and the duration of the winter cooling period is shortening[39]. The data indicated that a shortened winter season results in higher subsurface temperatures and earlier onset of summer stratification. The delay in fall overturn,

loss of ice, and collapse of the cooling period could ultimately change the annual thermodynamics of our dimitic Great Lakes to become monomictic. These potential shifts in the thermal regimes of the lakes would have profound impacts on their ecosystems.

The primary physical response of lakes to climate change will manifest as changes in water temperature, ice cover, water storage, and thermal structure. Moreover, changes in subsurface temperatures can result in changes to water column stability, mixing, and duration of stratification. CIGLR will work with the GLERL OSAT team to maintain year-round temperature strings to provide detailed vertically distributed water temperature data to analyze long-term trends and deep water dynamics. Subsurface observations began in 1990 at a 150 m deep location in the central southern basin of Lake Michigan and represent the most complete historical time-series for the Great Lakes. Observations are being expanded to the other upper Great Lakes, Huron and Superior.

Foci 1b. Mobile Observing Systems

Objective 1b.1: Advance mobile platform technologies for monitoring of physical, chemical, and biological parameters (core)

Potential PIs: CIGLR – Johengen, Fraker, Godwin, Miller (UM), Austin (UMD), Rudstam (Cornell), Greene (Cornell), Hashsham (MSU), Fisk (Windsor); GLERL – Ruberg, Mason, Vander Woude; Partners – Lenters (MTU)

Mobile observing platforms have the potential to monitor key parameters of ecosystem health (e.g., cyanotoxins, phosphorus, invasive species, microbial pathogens) in real-time at a reasonable cost. CIGLR Regional Consortium members, along with EPA's Large Lakes Research Station, now operate a network of 8 Slocum gliders and 2 IVER AUVs as part of their mobile platform operations. In addition, CIGLR is working with NOAA-GLERL to engineer and upgrade two new wave gliders with sensors to expand the array of mobile platforms. Regional Consortium members have been developing new molecular approaches that can be adopted for use on field-deployable platforms that could provide routine measurements for (1) eDNA of dozens of invasive species, (2) genes related to harmful algal blooms, waterborne pathogens, and antimicrobial resistance, and (3) chemical species of concern such as cyanotoxins and phosphorus.

Additional work to advance the utility of mobile observing platforms over the next five years includes the following: (1) Engineering work to make mobile platforms more compact, lightweight, lower in power consumption, and with flexible incorporation of in-situ environmental sensors (cyanobacteria, dissolved oxygen, temperature, chlorophyll, and photosynthetically active radiation). (2) Application of buoyancy and wave gliders to extend spatial and temporal scales of ongoing GLERL and EPA regionally-directed ecological monitoring programs. In particular, CIGLR glider missions will be developed to support science missions in each of the Great Lakes associated with priorities established for the EPA Coordinated Science and Monitoring Initiative. Glider missions can be directed to provide estimates of community metabolism that can be compared with laboratory measurements of net primary production, expand the temporal and spatial coverage of the monthly GLERL ecological monitoring program in Lake Michigan, provide real time hypoxia observations in Lake Erie central basin, and continue science operations in Lake Superior focused on climate impacts to thermodynamics. (3) Integration of a two-frequency, split-beam, fisheries acoustics system into a

SV2 wave glider to conduct long-term and high temporal frequency autonomous fish surveys that can be integrated into a real-time coastal observing network (ReCON) on Lake Michigan. (4) Design, validate, and deploy analytical devices with microfluidic cards capable of automatically analyzing at least 75 selected markers including cyanotoxins and associated functional genes, phosphorus, eDNA for dozens of invasive species, sentinel markers of antimicrobial resistance genes (e.g., integron-integrase IntI1), and indicators of waterborne pathogens. (5) Advance the application of mobile platforms by developing the capability to autonomously collect physical samples, adding a propeller propulsion mode for control in violent waves or rapid currents, integrating cellular and satellite communications modules to enable communication with other observing platforms throughout the Great Lakes, and developing planning and control algorithms to coordinate adaptive sampling capabilities.

Objective 1b.2: Conduct continuous underway monitoring of pCO_2 to examine the synergistic impacts of climate induced acidification, temperature, total alkalinity and nutrients on cyanobacteria HABs in the Great Lakes (emerging)

Potential PIs: CIGLR – Johengen, Godwin, Miller, Dick (UM); GLERL – Ruberg, Errera

Since 2009, NOAA-GLERL has conducted routine and standardized monitoring of cyanobacterial harmful algal blooms (cHAB) designed to detect spatial and temporal patterns and allow for interpretation of physical and chemical characteristics of the water column in western Lake Erie and Saginaw Bay. Starting in 2019, GLERL began routinely collecting data on inorganic carbon (C_i) concentrations, total alkalinity, pH, and pCO_2. Preliminary data suggests significant shifts in pH, C_i and NO_3^- occur as the cHAB develops. Prior to the bloom, pH is lower and NO_3^- is relatively abundant. Following bloom formation, biological uptake and biomass sequestration decreases pCO_2, pH increases to over 9.0, and NO_3^- availability drops significantly. Field studies utilizing continuous underway mapping will be conducted to supplement experimental studies aimed at evaluating how the co-limitation of both C_i and N shapes the composition and toxin production of cyanobacterial strains over the course of the bloom. Detailed continuous mapping can help resolve the highly heterogeneous spatial gradients in C_i concentrations that operate on sub-daily timescales. These highly dynamic patterns of pH, C_i and NO_3^- likely induce physiological changes within the bloom and spatial patterns will be further complex when currents are factored in due to strong influence of coastal riverine inputs.

Foci 1c. Remote and Airborne Observing Systems

Objective 1c.1: Enhance remote sensing systems to support integrated observation networks (core)

Potential PIs: CIGLR – Johengen (CIGLR), Sayers (MTU), Austin (UMD), Greene (Cornell), Heumann, Zheng (CMU), Qi (MSU), Shum (OSU), Grgicak-Mannion (Windsor); GLERL – Vander Woude, Chu

Remote sensing can provide a complementary source of data to in-lake systems at local to global scales. Environmental monitoring of the Great Lakes from space began in the 1970's with the Nimbus-7 and CZCS satellites and are now derived from a suite of airborne and satellite systems that include both radar and ocean color sensors. A primary focus of CIGLR's research in remote sensing will be to continue the ongoing transition of the new CPA remote sensing products to operational status within CoastWatch. CIGLR will continue interactions with GLERL and NESDIS regarding evaluation, model input upgrades, and calibration of CPA-A for experimental

use within NOAA's Great Lakes CoastWatch. A second major thrust will be to generate custom water quality data sets to support NOAA studies of harmful algal blooms and primary production in the Great Lakes. Using the CPA-A, we will generate a suite of weekly derived satellite products for each Great Lake on each cloud free day that includes HABs estimates in the western basin of Lake Erie. Results will be used to calculate annual HABs statistics and help assess progress towards GLWQA objectives. Additional research will focus on developing an operational Great Lakes Primary Productivity Model to provide monthly retrievals for potential implementation into Coast Watch.

CIGLR will continue to direct research focused on measurement of inherent optical properties throughout each of the Great Lakes to further refine CPA-A hydro-optical (HO) model performance. Measurements will be conducted to examine seasonal and spatial changes in IOPs due to shifts in phytoplankton composition and help quantify nearshore and offshore gradients in IOP. Research will help differentiate dominant sediment contributions from phytoplankton retrievals to improve HAB-specific hydro-optical models and estimations of HAB intensity and spatial extent.

Objective 1c.2: Develop remote sensing products using PACE satellite hyperspectral ocean color instrumentation (emerging)

Potential PIs: CIGLR – Johengen (UM); GLERL – Vander Woude, Ruberg; Partners – Sayers (MTU)

CIGLR will work with NOAA and regional partners to help develop improved remote sensing data products related to the launch of NASA's Plankton, Aerosol, Cloud and ocean Ecosystems (PACE) satellite. The hyperspectral Ocean Color Instrument on PACE can measure properties of light over broad portions of the electromagnetic spectrum at nm resolution. These observations will enhance key ecological, biogeochemical, climate, and aerosol data records for the oceans and Great Lakes. The higher resolution data will reduce uncertainties in climate and radiative forcing models and improve our understanding of carbon cycling in response to climate change.

Specific areas of emphasis for CIGLR and the Great Lakes community are the development of improved bio-optical algorithms and products to help address the detection and quantification of cyanobacterial harmful algal blooms (cHABs). Current remote sensing products are limited in their ability to differentiate specific phytoplankton communities and are challenged to measure cHABs at the early bloom development stage. Future work will build upon our ongoing efforts to develop semi-analytical bio-optical models utilizing taxa-specific spectral libraries and the in situ inherent optical properties database that we have developed over the past 10 years. New data products will be transitioned to NOAA GLERL for utilization and dissemination in CoastWatch and in the NOAA Lake Erie Harmful Algal Bloom Forecast.

Objective 1c.3: Develop remote sensing products in support of EPA GLNPO Great Lakes monitoring program (emerging)

Potential PIs: CIGLR – Johengen (UM); GLERL – Vander Woude, Rowe, Ruberg; Partners – Sayers (MTU)

Research activities supported during this renewal proposal will include the development of new remote sensing products to supplement EPA GLNPO's historical ship-based monitoring efforts, to aid in development of best sampling practices, and to validate current and future remote sensing products. Monthly satellite derived water quality products for chlorophyll, water clarity (Kd, photic depth, secchi depth), suspended solids, CDOM, and bulk optical properties (absorption, beam attenuation, scattering) will be generated for comparison with EPA's historical

bi-annual ship based biological monitoring surveys. In particular, remote sensing products for chlorophyll will be validated by comparing near-coincident (time and space) with *in situ* observations obtained during the R/V Lake Guardian cruises. Research will be directed to establish a methodology that will allow for product retrieval inter-comparisons of SeaWiFS (1998-2010), MODIS (2002-present), VIIRS (2012-present), and PACE (2022 -) data for the generation of monthly water quality parameters identified above. Remote sensing derived products will be analyzed to demonstrate their utility to augment the spring and summer Lake Guardian cruises. Satellite maps will be generated that fill the spatial area of the lakes where the Lake Guardian does not sample during their surveys, as well as the periods between cruises. Lastly, we will support a proof-of-concept study (algorithm development and evaluation) to assess the capability of space-borne Lidar to estimate zooplankton populations. These data products can again be compared against ship-based sampling efforts within both EPA and NOAA-GLERL ecological monitoring programs.

Objective 1c.4: Advance airborne platform technologies for improved lake-scale assessments of harmful algal blooms (core)

Potential PIs: CIGLR – Johengen, Miller (UM); GLERL – Ruberg, Vander Woude

Airborne platforms can generate significantly improved observations and data products compared to satellite estimates alone. The application of aerial drones could reduce costs even further and increase the frequency at which observing missions can be conducted. In addition, the high bandwidth and resolution provided by new hyperspectral sensor technologies implemented on airborne platforms provides an opportunity to better resolve phytoplankton classification and to improve accuracy of HAB forecasts. CIGLR will continue to support the development of state-of-the-art airborne platforms, including autonomous drones and integrated sensor technologies, to provide improved spatial resolution of remote sensed observations near critical nearshore zones where public water utilities operate and tributary pollutant inputs occur. Weekly hyperspectral overflights during the HABs growing season (July – October) will be continued, with the additional focus of resolving specific phytoplankton functional types (PFTs) from the remote sensing reflectance values (Rrs). Improved classifications will lead to better forecasts in Lake Erie to inform water intake managers of the location of HABs (i.e., cyanobacteria). The historical *in situ* absorption, scattering, and attenuation spectra collected by CIGLR and GLERL will also be used to differentiate functional groups from past *in situ* monitoring of inherent and apparent optical properties and the dominant bloom forming groups observed during previous field seasons. Verification of the final algal classifications estimations from hyperspectral sensors can be conducted from comparison of surface mapping with a multi-excitation fluorometry as well as from pure laboratory cultures. We will work with NOAA-GLERL and NCCOS to automate and calibrate data processing of the hyperspectral observations for inclusion in the NOAA Lake Erie Harmful Algal Bloom Forecast. Inclusion of these data can provide improved information on community dynamics throughout the bloom period by pulling out different functional groups of phytoplankton.

Objective 1c.5: Improve the utility of data products for Great Lakes CoastWatch through stakeholder engagement (core)

Potential PIs: CIGLR – Johengen, Miller (UM), Triezenberg (MSU); GLERL – Vander Woude, Ruberg

CoastWatch is a NOAA-wide program that provides a rapid supply of up-to-date, coordinated environmental information (remotely sensed, chemical, biological, and physical) to support

federal and state decision makers and researchers who are responsible for managing the nation's coastal ecosystems. NOAA CoastWatch focuses on specific regional priorities, such as unusual environmental events (e.g., harmful algal blooms), mapping wetland change (e.g., change detection), and mapping ice cover/ice thickness (e.g., hazard mitigation). The goal of this project is to support the Great Lakes CoastWatch program's ability to develop and deliver real-time and retrospective satellite observations and derived products for the Great Lakes. These regional products and applications for the Great Lakes will contribute to operational responsibilities multiple federal entities, such as the U.S. Coast Guard and NOAA National Weather Service, and will foster additional research applications by regional data users, such as detection and tracking of thermal fronts, analysis of circulation patterns and upwelling (e.g., fish recruitment studies), and modeling and forecasting Great Lakes parameters (e.g., Great Lakes Forecasting System (GLCFS)). All Great Lakes CoastWatch products are publicly available on the Great Lakes CoastWatch website.

To promote usability of these remote-sensing products, CIGLR will engage stakeholders in co-design of the user-interface for the products, as well as updates to the Great Lakes CoastWatch website. Additionally, CIGLR's Stakeholder Engagement Specialist will work specifically with users of the Michigan State University (MSU) CoastWatch Lake Surface Temperature contour data plot, including members of the fishing community, to integrate this product into the updated Great Lakes CoastWatch website. Lastly, CIGLR will support an outreach component within its remote sensing efforts aimed at disseminating scientific information for the general public, highlight NOAA research initiatives in the region, and provide training opportunities for students, teachers, and the general public. We will provide outreach presentations and tutorials and social media content on behalf of NOAA through both GLERL and CIGLR channels.

Focus 1d. Winter and Year-Round Observations

Objective 1d.1: Coordinate a regional winter sampling campaign (emerging)

Potential PIs: CIGLR – Ozersky, Austin (UMD), Johengen, Godwin (UM), Carrick (CMU); GLERL – Ruberg, Vanderploeg, Mason, Rutherford

In 2019, CIGLR supported a summit on winter limnology to evaluate critical information gaps and key winter observations needed for understanding and forecasting ecosystem responses and adaptation to change. A fundamental conclusion of the evaluation was that the absence of winter information compromises our overall understanding of the Great Lakes ecosystem and our ability to develop and calibrate ecological and food web models to forecast change or the ecosystem's response to anthropogenic drivers. Knowledge gaps include basic information on ice properties, water thermal and mixing regimes, concentrations of nutrients, and abundances of important organisms and their community dynamics. Recently, with support from CIGLR, a network of Great Lakes researchers (Great Lakes Winter Network; GLWiN) has coalesced around a common interest in coordinated winter sampling and a set of priority research questions. An initial effort of the network was to develop a regionally directed and coordinated winter sampling effort by the CIGLR Regional Consortium and federal agency partners. This initial winter sampling campaign was piloted in February 2022 by 18 research groups that expressed interest in participating in sampling and/or sample analyses. Sampling efforts included characterization of ice properties (thickness, light attenuation), water column physical and chemical conditions (temperature, clarity, conductivity, oxygen, nutrients, etc.), and biological patterns and processes

(plankton biomass and community structure, primary and bacterial production rates). CIGLR will support ongoing efforts by GLWiN to continue the development of a winter sampling program and help look for necessary resources and infrastructure support to coordinate data sharing and the long-term sustainability of the sampling campaign.

Objective 1d.2: Use under-ice mobile platforms to make winter observations (emerging)

Potential PIs: CIGLR – Johengen, Miller (UM); GLERL – Ruberg, Mason

In a longer-term effort to expand the capacity for conducting winter observations, CIGLR will work with NOAA-GLERL and federal partner USGS to integrate and apply available autonomous technologies with remote sensing capabilities for measuring environmental conditions and the winter spatial distribution and abundance of important food web components, i.e., zooplankton, *Mysis* and pelagic planktivorous fishes. In the first phase of this project, we will collaborate with university and private industry (Saab) to integrate an ASL AZFP (https://aslenv.com/azfp.html) four-frequency (70 KHz, 120 KHz, 200 KHz, 760 KHz) acoustics system and environmental sensors with the Slocum glider and Saab Sabertooth. In the second phase of this project, we will pilot deployments during the ice-free winter months to further test the integrated system and evaluate the efficacy to measure the winter spatial distribution, abundance and size distribution of zooplankton, *Mysis* and pelagic fishes. A third phase of the project would be to demonstrate the system's capability for long-duration integrated multi-frequency acoustics observations of zooplankton, *Mysis*, and fish during ice-free and iced conditions, both day and night, for Lakes Michigan, Superior, and Erie. Deployment location will depend on the existence of ice cover. This will also demonstrate the portability of the integrated system. The ultimate goal of this project is to develop the capacity for sustained winter observations of zooplankton, *Mysis*, and fish and have these observations become an operational component of GLERL's long-term ecological research program.

Foci 1e. Human Dimensions Observing Network

Objective 1e.1: Develop and deploy social observing systems: the Great Lakes Observing System for Human Dimensions (GLOS-HD) (emerging)

Potential PIs: CIGLR – Lupi (MSU), Dietz (MSU), McCright (MSU), Franks (MSU), Moore, Hughes (UM), Boyer (UWM); Partners – Erickson (NERR)

Effective management of Great Lakes ecosystems requires that we consider the socioeconomic and sociocultural elements of the human communities that live within the basin and rely on their ecosystem services. Great Lakes social observation systems and basin-wide data are severely lacking in this regard, especially at actionable scales where social science can deliver information to decision-makers and inform policy. To complement the strong biophysical monitoring systems that presently exist, CIGLR will promote the development of the Great Lakes Observing System for Human Dimensions monitoring program. Future projects in this area can also take advantage of NOAA's place-based program – the NERRs and the Sanctuaries – to develop, deploy, test and refine an observing system that collects and analyzes key sociocultural and socioeconomic data for coastal communities.

To develop a tractable human dimensions observing system, initial efforts will focus on collecting data that relates to human health, water quality, and shoreline recreation through an examination of related social, cultural and economic services that are attached to these. Services

that can be quantified economically include (a) recreational uses of shoreline beaches and parks for use in valuation studies that rely on travel cost methodologies, (b) shoreline property sales and values for use in hedonic pricing studies, and (c) Great Lakes-dependent coastal businesses sales and profits for use in market valuation studies. Non-economic metrics of social or cultural values can be quantified from repeated surveys of users sense of place, identity and the value of local heritage. HD observations can be collected via: (1) a broad-based collection of existing and remotely collected data (e.g., data mining, social media, webcams); (2) systematically designed, randomized surveys to quantify coastal residents' activities and social values related to them (e.g., shoreline visitation, fishing, cultural practices); and (3) focused in-depth interviews and qualitative analysis of smaller subsamples in concert with place-based programs to measure attitudes, satisfaction, place attachment and broader values. The development of a GLOS-HD would fill a key gap in the currently sporadic efforts to measure economic, social, or cultural values of Great Lake ecosystem services, and form the basis needed by managers to understand how constituencies interact with the Great Lakes.

Theme 2. Invasive Species and Food-web Ecology
Tracking the dynamics and functioning of Great Lakes ecological communities

The communities of microbes, plants and animals that inhabit the Great Lakes provide valuable ecosystem services. However, invasions of exotic species have profoundly altered and disrupted Great Lakes food webs, with massive ecological and economic and impacts[12]. Climate change, habitat loss, pollution, nutrient runoff, and other anthropogenic insults also threaten Great Lakes ecosystems and biodiversity. Understanding how Great Lakes biodiversity and ecosystem dynamics respond, and determining the consequences for natural and human systems, is essential to achieving biological and economic sustainability. CIGLR will focus on 3 areas of research for Theme 2: invasive species, food-web dynamics, and harmful algal blooms. We will also continue to lead development of 'omics approaches, which have potentially game-changing applications to all three research areas.

Focus 2a. Invasive species

Objective 2a.1: Determine community and ecosystem impacts of invasive species (core)

Potential PIs: CIGLR – Godwin, Chaganti, Denef (UM), Ozersky (UMD), Lodge, Rudstam (Cornell), Ivan, Lupi (MSU), Carrick (CMU), MacIsaac (Windsor); GLERL – Elgin, Rutherford, Mason, Vanderploeg

CIGLR has considerable experience working with NOAA-GLERL to quantify the ecological effects of invasive species on algae[13], nutrient dynamics[14-16], and lake productivity[17]. We will continue to broadly support NOAA-GLERL's research on invasive species with studies that detail their ecological and economic impacts. CIGLR will engage in research that characterizes the nature and magnitude of food web disruptions in the Great Lake such as (1) surveys, experiments, and biophysical models that predict the impacts new invaders, such Asian carp, on Great Lakes food-webs and fisheries[18]; (2) experimental, observational, and modeling approaches to understand the food-web consequences of exotic species; (3) empirical approaches to assess impacts of invasive species on trophic communities in riverine and stream ecosystems.

CIGLR will focus its efforts on quantifying and understanding the impact of key invasive species such as dreissenid mussels, which have had profound and divergent impacts on trophic structure,

nutrient dynamics, microbial communities, productivity, and energy flow in the Great Lakes. Following the invasion and expansion of dreissenid mussels in the Great Lakes, primary production that supports the food web declined in most regions, resulting in crashes of commercially important fisheries in Lakes Michigan and Huron. In other parts of the basin, such as western Lake Erie and Saginaw Bay, dreissenid invasion contributed to the worsening of cyanobacterial harmful algal blooms by selective feeding on the phytoplankton community. Several CIGLR research thrusts are aimed at understanding the ongoing direct and indirect ecological effects of these invasive mussels. First, we will coordinate comparison of fundamental methods used to measure primary production, including (1) conventional radioisotope methods that are complicated due to hazards and restrictions aboard vessels, (2) alternative stable isotope methods, and (3) an emerging technique to measure production via buoyancy and shallow-water glider missions. Second, we will continue to assess the effects of invasive mussels on microbial community structure and function and the associated implications for lower and upper food web and ecosystem processes. Third, we will study and project the impacts of the invasive round goby, which show signs of potentially stabilizing invaded ecosystems through mussel predation.

Objective 2a.2: Use eDNA for monitoring and early detection of invasive species (emerging)

Potential PIs: CIGLR – Chaganti (UM); Lodge, Gomez, Hare, Getchell, Therkildsen, McComas (Cornell); MacIsaac (Windsor); Sepulveda-Villet, Cuhel (UWM); GLERL – Elgin, Rutherford, Errera

'Omics technologies have become powerful tools for surveillance and monitoring of organisms in natural environments (see *Focus 2d*). Members of the CIGLR Regional Consortium pioneered the development and application of environmental DNA (eDNA) tools to the surveillance of invasive species in the Great Lakes watershed, refined the eDNA approach to detect many species from the same analysis, and adapted eDNA approaches for citizen science, thus expanding the scope of sample collection while simultaneously educating the public. Consortium laboratories have state-of-the-art facilities, equipment, and procedures to prevent contamination and assure high quality environmental genomics data. CIGLR PI Rao Chaganti is at the forefront of emerging eRNA methods for linking molecular data to quantitative and temporal dynamics of invasive populations.

CIGLR will continue to develop eDNA and eRNA approaches for surveillance and monitoring of invasive species. Specifically, we will (1) expand tools for use on a wider variety of taxonomic groups by leveraging rapidly advancing shotgun sequencing technologies that capture data on organisms from across the entire tree of life; (2) optimize sampling strategies for different taxonomic groups and habitats (benthic vs. pelagic); (3) optimize laboratory procedures and bioinformatics pipelines to extract population level inferences and spatial and temporal information on species distributions from sequence data; (4) develop genetic markers and qPCR methods for rapid detection and identification of invasive and economically important species; (5) calibrate eDNA/eRNA methods with conventional sampling; and (6) working with our industry partners, develop, test, and improve technologies for generating near real-time genetic data streams from field deployment of autonomous platforms.

Objective 2a.3: Predict, prevent, and manage species invasions with a coupled social-ecological-engineering systems approach (emerging)

Potential PIs: CIGLR – Fischer, Moore (UM); Stedman, Knuth, Lauber (Cornell); GLERL – Vanderploeg, Rutherford, Elgin, Mason

Human actions and behaviors contribute to introductions of invasive species as well the efficacy of prevention, management, and eradication efforts. CIGLR will address the social-ecological networks of aquatic invasive species in the Great Lakes with research to better understand (i) how human behaviors contribute to the introduction and spread of invasive species; (ii) how individuals and institutions deal with the problem of invasive species; (iii) how governance networks account for ecological interdependencies that exist in the ecosystem, (iv) the feasibility of engineered solutions to invasive species; and (v) the economic costs of invasive species[19], including costs and benefits of approaches to managing them. We will work with GLERL and other partners to test the feasibility of engineering solutions to invasive species, such as robotic removal of dreissenid mussels and technologies for detecting and/or removing invasive species from ballast water. CIGLR's Regional Consortium will continue to develop economic models of recreational and commercial fishing demand and value and then use this information to build empirical models that help quantify the potential economic losses associated with invasive species and other impairments to recreational fisheries[20].

Outputs of this research will be used to effect policy approaches for limiting introductions and spread of invasive species as well as managing those that are already established. Translation of research to outcomes will be facilitated with summits and working groups aimed at synthesizing current knowledge and critical gaps, identifying key needs for policy interventions and technology development, and developing strategies for managing the coupled human-ecological network of aquatic invasive species in the Great Lakes. Finally, CIGLR will conduct outreach, engagement, and education activities to coordinate and enhance invasive species control and management efforts around the region, leveraging our partnerships with Sea Grant programs in Great Lakes states, the Great Lakes Commission, and GLERL's involvement with the Great Lakes Panel on Aquatic Nuisance Species.

Focus 2b. Food-web dynamics

Objective 2b.1: **Monitor pelagic ecosystems with conventional and advanced methods (core)**

Potential PIs: CIGLR – Rudstam, Sullivan, Watkins, Greene (Cornell); Fisk (Windsor); Johengen, Fraker, Godwin (CIGLR); Carrick (CMU); GLERL – Vanderploeg, Rutherford, Mason, Vander Woude

CIGLR will continue to work with the Ecosystem Dynamics branch at NOAA-GLERL on their collection of long-term ecological data to improve our understanding of ecosystem structure and function in the Great Lakes. Future research activities will be developed to support both recurrent vessel-based surveys, process-based lab experiments, and integration of emerging technologies ('omics, acoustics, remote sensing, isotopes, gliders) that overcome key challenges of monitoring at appropriate spatiotemporal scales. These research activities will be centered in Lake Michigan, but we will also support NOAA, USGS, and EPA research efforts within the other Great Lakes as part of the EPA Coordinated Science and Monitoring Initiative (CSMI). CIGLR recently added a suite of methodological capabilities to this long-term monitoring that include: measurements of primary production by ^{13}C and ^{14}C uptake, measurement of community metabolism by glider deployments, and size-fractionated measurements of inherent optical properties of water and seston.

Fisheries acoustics is used extensively for stock assessment in both marine and freshwater systems, but application of acoustics to invertebrates is still limited. We will leverage advances

in hardware, theory, statistical analysis, and deployment platforms, to expand applications of acoustics to track the distribution and abundance of more biological components of the pelagic ecosystem. For example, zooplankton distributions will be tracked over large spatial scales using multifrequency hydroacoustics data. These data will be collected in conjunction with Multiple Opening Closing Nets Environmental System Sampler (MOCNESS) at NOAA-GLERL, which allows for detailed investigations of the identity of various scattering layers in the Great Lakes and will help calibrate acoustic estimates. We will also expand our use of acoustics to follow the movement of individual fish in collaboration with the Great Lakes Acoustic Telemetry Observation System (GLATOS) network. These data give information on the large-scale movement patterns of predatory fish as well as environmental information about the water column as they travel through it. Moving forward, we envision that this core ecological monitoring will be integrated projects to track spatial and temporal dynamics of habitats ("lakescapes") and with genetic data derived from genomic observatories (see *Obj 5b.1*).

Objective 2b.2: Assess coupling between benthic and pelagic food web dynamics with long-term monitoring and targeted experiments (core)

Potential PIs: CIGLR – Johengen, Fraker, Godwin (CIGLR), Carrick (CMU), Denef (UM); GLERL – Elgin, Mason, Vanderploeg, Rutherford, Rowe

CIGLR will collaborate with the Ecosystem Dynamics branch at NOAA-GLERL to continue their collection of long-term ecological data that are critical for understanding ecosystem structure and function, and how they are changing due to climate change and anthropogenic forcing, for managing water quality, fisheries, and other ecosystem services in the Great Lakes. The current Long-Term Research (LTR) program of GLERL integrates a core set of long-term observations on biological, chemical, and physical variables, with short-term process-based studies for understanding ecosystem change. Such information is essential for the development of new models and forecasting tools to explore impacts of various stressors on the ecosystem.

Future research activities will support recurrent vessel-based spatial surveys, process-based studies, and implementation of emerging sampling technologies to provide data for the development of models and forecasting capabilities. The geographical scope of these research activities will be centered in Lake Michigan; however, we will also support NOAA, USGS, and EPA research efforts within the other Great Lakes as part of the EPA Coordinated Science and Monitoring Initiative (CSMI). CSMI studies are aimed at examining structure and function of the open water food web and relating patterns across lakes to major drivers such as tributary inputs and spatial distribution of invasive dreissenid mussels. CIGLR will continue to support long-term observations of dreissenid abundance and condition in the southern Lake Michigan basin. These data will be combined with experimental research on feeding and nutrient excretion rates to develop models of mussel population growth and bioenergetics and to develop models of mussel impacts to the food web. CIGLR will continue to conduct laboratory experiments to determine selective feeding on the whole spectrum of seston (from bacteria to microplankton), quantify nutrient recycling, and examine factors limiting growth of mussels in Lake Michigan. We will support in-lake experiments to assess quagga mussel growth under different levels of food quantity and quality, and in different temperatures using in situ mussel cages, and extend this work with complementary biophysical modeling.

Objective 2b.3: Inform restoration and conservation of coastal wetlands with long-term ecological assessment and modeling (core)

Potential PIs: CIGLR – Uzarski (CMU), Ruetz (GVSU), Currie (UM); GLERL – Vanderploeg (GLERL)

Since European settlement, more than 50% of coastal wetlands have been lost in the Great Lakes basin, leading to growing concern and increased monitoring by government agencies. Sound management stems from data-driven decisions of ecosystem functions and values. These data are not currently available. To facilitate collaboration and information sharing between public, private, and government agencies throughout the Great Lakes basin, we developed standard methods and indicators used for assessing wetland condition by multiple universities and government agencies across the Great Lakes basin. In 2011, we initiated sampling efforts in which physico-chemical and biotic data are collected from all components of wetlands. After quality assurance/quality control these data are entered in mathematical models and stored in a publicly accessible database greatlakeswetlands.org. We plan to continue these ecological assessments, with the goals of (1) incorporating functional assessment protocols; and (2) linking these functions to nearshore and offshore waters to develop energy flow models to inform managers and lawmakers.

To complement these ecological assessments and use the data to address a broader variety of research questions, we plan to expand and apply complex ecosystem process models of Great Lakes coastal wetlands that have been developed with the CIGLR Regional Consortium. These models include N and P cycling and their transformations and retention in coastal wetlands, C storage, and complex feedbacks with wetland plant community dynamics including invasive plants such as non-native *Phragmites*, which outcompete native plants. The models will also include fluctuating wetland water levels, as well as hydraulic inflows and outflows including flushing rates and hydraulic residence time, driven in part by seasonal and interannual changes in stream flows and fluctuating lake levels. Simulation of wetland P retention and legacy P release from wetland sediments will inform models of P loading to the Great Lakes.

Focus 2c. Harmful algal blooms

Objective 2c.1: Monitor enduring and emerging blooms (core)

Potential PIs: CIGLR – Godwin, Chaganti, Kharbush, Dick, Cory, Denef, Duhaime (UM), Miller (UWM), Sheik, Sterner (UMD), Chaffin (OSU); GLERL – Errera, Vanderploeg

CIGLR has played a key role in core monitoring programs that track the development, toxicity, community dynamics, and environmental parameters of harmful algal blooms, which are a growing threat to water quality and ecosystem health in the Great Lakes and in freshwaters around the world. This monitoring provides critical observations needed for developing and testing predictive models that forecast the formation, spread, and toxicity of harmful algal blooms (see *Obj 3c.1*). Regional Consortium members (UWM) have expanded research and monitoring into Green Bay, WI. Routine monitoring programs will continue in Lake Erie, Saginaw Bay, and Green Bay. We will also expand monitoring efforts in Lake Superior, where blooms have emerged in recent years, through collaboration with Regional Consortium member University of Minnesota Duluth. Monitoring programs will characterize HAB intensity, toxicity, and water quality (nutrients, turbidity, optical properties) throughout the water column. Sampling intensity and spatial extent will depend on the timing and extent of HABs indicated by satellite imagery. We aim to sample weekly through the bloom season (Jul-Oct), with initial sampling in

May to evaluate antecedent conditions. Data will be used to (1) provide information on toxin concentrations and distributions with water users, (2) elucidate the drivers of bloom development and subsequent movements through ecosystems, (3) share field sampling results with NOS for use in the Lake Erie HAB Bulletin, and (4) support further model development.

Objective 2c.2: Leverage the Great Lakes HABs culture collection to determine ecophysiological traits of major bloom-forming cyanobacterial species (core)

Potential PIs: CIGLR – Godwin, Chaganti, Dick, Denef, Duhaime (UM); Sheik (UMD); Chaffin (OSU); GLERL – Errera

Next generation models have potential to improve our forecasting and understanding harmful algal blooms by incorporating knowledge of underlying biological processes that govern bloom development, toxin production, and biotic interactions (*see Obj 3c.1*). Explicit integration of cellular and ecological mechanisms into models enables simulation and prediction of emergent processes that may not be captured by statistical modeling with patchy data. However, until recently, key biological parameters of major bloom-forming cyanobacterial species were unknown because Great Lakes strains had not been cultured or studied in the laboratory. CIGLR has addressed this issue by isolating a diversity of *Microcystis* and *Dolichospermum* strains, which are the main bloom-forming taxa from Lake Erie and Lake Superior. We will use this strain collection to conduct experiments aimed at defining key ecophysiological parameters of cyanobacterial species needed to inform next generation models. This includes determining resource competition traits (growth responses to nutrients such as N, P, and C); stress response traits (growth response to temperature, light, and pH); interference competition traits (allelopathy); and defense traits and mortality parameters (resistance to phage, grazing). In concert with sequencing of genomes, transcriptomes, metabolomes, and proteomes of these lab-cultured organisms, this research objective will also reveal relationships between phenotypic traits and genetic traits. Through comparison with ‘omics data from the field, this research will link knowledge derived from lab experiments to field observations (se *Obj 2d.1*).

Focus 2d. Development of ecological ’omics

Objective 2d.1: Track the structure and function of Great Lakes microbial communities (emerging)

Potential PIs: CIGLR – Chaganti, Dick, Denef, James (UM); Sheik (UMD), Alm, Learman (CMU); Rich (OSU), Newton, McLellan (UWM); McKay, Weisener (Windsor); GLERL – Errera

Microorganisms, including bacteria, archaea, and microbial eukaryotes, regulate important ecosystem-level processes such as the flow of energy, cycling of biologically essential nutrients, and transformation and breakdown of pollutants. At the same time, microbes are the underlying cause of some of the greatest environmental problems faced in the Great Lakes, including toxic cyanobacterial blooms and waterborne pathogens. Until recently, microbiologists lacked the tools needed to perform routine surveys and monitoring of microbes, which precluded us from predicting their diversity, spread, and whether their functions are beneficial or detrimental. But recent advances in DNA and RNA sequencing technology have given microbial biologists the unprecedented ability to survey microbes in near real-time, and advances in computational algorithms and databases have provided the means for analysis and dissemination of large genomic datasets. We are, for the first time, in a position to open the black box of the Great

Lakes microbial communities and begin tracking and predicting their beneficial and detrimental functions.

We will (1) characterize the diversity of microbes across the Great Lakes; (2) mine these datasets to identify indicator organisms and function of interest, including genes that encode ecosystem processes, ecological interactions, and production of known and emerging toxins and other natural products; (3) apply advanced statistical and machine learning tools (see *Obj 5c.2*) to investigate spatial, seasonal, and inter-annual patterns of diversity and function and to determine how they are related to environmental and biotic drivers and disturbances (climate change, extreme storms, species invasions); and (4) incorporate 'omics data into ecological models through parameterization and/or validation. These goals will be achieved through multi-year sampling of all 5 Great Lakes, high-throughput multi-'omics sequencing, and development and application of advanced bioinformatics pipelines. Data will be archived in a searchable, open access database for dissemination to other researchers (*See Obj 5c.1*).

Our understanding and predictive capacity for food web responses to altered ecological states will be strengthened by studying prey-predator interactions (including allelopathic interactions) of the microbial food web. A major outcome of this work will be to revise and update existing food web models, which will enable us to project changes in energy flow from pre- to post-mussel invasion in food web dynamics and fishery production. Overall, this project will advance the NOAA 'Omics Strategy and implement the NOAA 'Omics strategic plan and the OAR Strategic plan by developing cutting edge 'omics tools that aid in fisheries management, biodiversity monitoring, and natural products discovery. Further, it addresses the Coordinated Science and Monitoring Initiative (CSMI) priorities and Great Lakes Fisheries Commission priorities. Additionally, this research has the potential to build strong collaborations between PIs from CIGLR and GLERL with PMEL and AOML in a unified effort to understand food-web dynamics.

Objective 2d.2: Use eDNA and 'omics to monitor the abundance, distribution, and stressors of rare, threatened, and commercially important vertebrate species (emerging)

Potential PIs: CIGLR – Chaganti, Dick (UM); Lodge, Getchell, Therkildsen, McComas, Hare (Cornell); Heath (Windsor); GLERL – Errera, Rutherford, Mason

Multiple studies now show that eDNA methods can be faster, cheaper, and better at detecting low-density target species than traditional methods. CIGLR will continue to develop and apply eDNA methods for surveillance and monitoring of rare, threatened, and commercially important species. For example, challenges with identification of larval fish will be resolved by developing species-specific genetic markers for regular, rapid and accurate identification using quantitative PCR (qPCR). eDNA data will be compared and calibrated with laboratory experiments on captured fish. eDNA tools will also be expanded for use on a wider variety of taxonomic groups of interest to GLERL. Results will make will be contributions to ecosystem management by providing information on the distribution and abundances of species, which is vital for effective management strategies related to stocking and harvesting decisions within the Great Lakes.

In addition to advancing and using eDNA methods for studying abundance and spatial distribution of species, CIGLR will also pioneer the use of 'omics methods for detecting and determining effects of pharmaceuticals, PFAS, and other emerging contaminants on Great Lakes species and ecosystems. Chemical compounds from human wastewater, such as caffeine, acetaminophen, and metformin (a type 2 diabetes drug) can now be detected far offshore in the

Great Lakes[31]. PFAS and other contaminants threaten commercial and tribal fisheries in the Great Lakes region. Our understanding of the individual and combined effects of these chemicals on aquatic organisms are in their infancy, but the impacts appear to be significant[32]. CIGLR will play a leading role in identifying impacts of emerging contaminants and assessing their risks through next generation methods, i.e., by detecting the effects of chemicals on biochemical pathways, genes, and tissues. We will do so through (1) extension of cellular and mouse models of exposure to fish; (2) laboratory experiments aimed at identifying new biomarkers of stressors; and (3) targeted and untargeted molecular surveys of Great Lakes specimens and field samples. Overall, development of these methods will enable the use of Great Lakes aquatic communities as important sentinels of environmental contamination and potential human health effects.

Theme 3. Great Lakes Hydrometeorological and Ecosystem Forecasting
Modeling physical and biological processes to help predict the Great Lakes future

Hydrometeorological and ecosystem forecasts rely heavily on both monitoring to describe changing environments, and modeling to translate those changes into quantifiable terms that can be predicted into the future. Theme 3 supports NOAA's priority of providing information and services to make communities more resilient by advancing Earth system and ecosystem models, data assimilation, and ecological forecasting, as well as increasing operational services that promote coastal resilience. To improve ecosystem forecasting for the Great Lakes, the renewed CIGLR will focus on 3 areas of research for Theme 3: Hydrological/hydrodynamic models and forecasts, climate and weather forecasts, and ecosystem state forecasts.

Focus 3a. Hydrological/hydrodynamic models and forecasts

Objective 3a.1: Improve hydrological forecasts through integration of the Great Lakes and Lake Champlain into the National Water Model (core)

Potential PIs: CIGLR – Beletsky, Gronewold (UM); Kelly (UMD); GLERL – Rowe, Fry, Lofgren

CIGLR, GLERL, and partners are working to integrate Great Lakes and Lake Champlain hydrological data into the new NOAA National Water Model (NWM). The NWM is an operational hydrologic model that simulates observed and forecast streamflow over the entire continental United States. The CI has been working with GLERL to develop the Weather Research and Forecasting hydrological modeling extension package (WRF-Hydro) to be incorporated into the new NWM for the Great Lakes and Lake Champlain region.

CIGLR will continue to integrate Great Lakes bathymetric data into the WRF-Hydro NWM, modify WRF-Hydro input/output functions to improve reservoir water management accounting, and conduct reservoir level data assimilation experiments. We will also continue to integrate the Great Lakes Aquatic Habitat Framework into WRF-Hydro simulations in the Great Lakes region. This project will also create critical datasets and data layers in uniform format that can be used for future development of the Great Lakes Forecasting System (GLCFS). This work will result in new modeling capabilities ready for deployment into the existing operational NWM, thus integrating the Great Lakes and Lake Champlain into NWM's visualization tools, which will be used by the National Weather Service (NWS) to improve their flood prediction capabilities. Data outputs will also provide valuable boundary condition inputs for other lake-scale ecological forecasting models.

Objective 3a.2: Improve water level forecasts for shipping and commerce with enhanced water level models (core)

Potential PIs: CIGLR – Beletsky, Gronewold, Kerkez (UM); Roebber (UWM); GLERL – Fry, Rowe, Lofgren

In support of the International Joint Commission's (IJC) need for understanding water levels and future water supplies in the Great Lakes, CIGLR will develop new models to improve Great Lakes water budget estimates and water level simulations. We will couple hydrodynamic and hydrologic models to improve predictions of hazardous conditions in Great Lakes ports and harbors. We will create a new historical record of monthly runoff, over-lake evaporation, over-lake precipitation, and connecting channel flows for each of the Great Lakes using a novel statistical model that (through an explicit acknowledgment of bias and uncertainty) reconciles discrepancies between model- and measurement-based estimates of each component while closing the Great Lakes water balance. We will also develop a new, authoritative, coordinated numerical model that efficiently and accurately simulates water levels and connecting channel flows in the Great Lakes system given user-specified net basin supply (NBS) scenarios. The goals of this project are to provide a robust historical dataset for each Great Lake that explains changes in observed water levels based on the relative importance of each component of the water balance, and to provide a relatively simplified water level modeling framework designed to meet current and future needs of regulatory authorities. This project is expected to result in the first comprehensive water budget estimate for the Great Lakes system that systematically closes the entire water balance, while addressing both measurement bias and uncertainty. It will also produce a suite of modeling products that are primarily intended for members of the IJC's Great Lakes-St. Lawrence River Adaptive Management Committee, water resources management staff from NOAA, USACE, and Environment Canada, and members of the Coordinating Committee on Great Lakes Basic Hydrologic & Hydraulic Data. Results will be included in NOAA's Great Lakes Water Level Dashboard.

Objective 3a.3: Develop the next generation Great Lakes coastal forecast system (core)

Potential PIs: CIGLR – Beletsky, Fujisaki-Manome, Gronewold (UM); Bravo (UWM); Mantha (MSU); GLERL – Wang, Titze, Fry, Rowe

CIGLR will continue to support NOAA-GLERL in the transition from research to operations (R2O) of the next generation (generation 3) NOAA Great Lakes Coastal Forecasting System (GLCFS[21,22]). The operational GLCFS is run by the National Ocean Service as part of the Great Lakes Operational Forecasting System. The 3rd generation of GLCFS uses the Finite Volume Coastal Ocean Model (FVCOM[23]) and began its transfer to operations in 2015, starting with the Lake Erie Operational Forecasting System (LEOFS[21,24]). Currently, FVCOM and an ice model coupled to it based on Los Alamos Sea Ice Model is running in the demonstration mode for all of the Great Lakes at the National Ocean Service. CIGLR will continue to conduct model analyses and evaluations to facilitate and complete R2O for the Great Lakes, as well as further model development. The goals of this work are to (1) improve the flux algorithm for heat and evaporation in the operational Great Lakes forecasts, (2) investigate lake hydrodynamics and the accuracy of hydrodynamic modeling as they relate to harmful algal blooms (HABs) and hypoxia, (3) improve understanding of factors and processes of thermal structure in the Great Lakes, including the roles of ice cover and its phenology, (4) explore the quality of alternative meteorological forcing functions, (5) integrate waves, wave-current interactions, sediment transport and entrainment into GLCFS, leveraging advances in modeling of multi-grained

cohesive and non-cohesive sediments in order to improve predictions of alongshore sediment transport, nutrient transport, and nutrient entrainment, (6) assess the role of groundwater on coastal waters, including thermal structure, hydrodynamics, and the effects of temperature on dissolved oxygen, (7) assess the potential for artificial intelligence and machine learning to improve the skill of the Great Lakes water level forecast by leveraging data on underlying hydrology, climate indices, etc. (see *Obj 5c.2*), (8) expand GLCFS into Great Lakes ports and harbors, and (9) test the coupling interface using the for future integration into the Unified Forecast System (UFS).

Products will include an improved bulk flux algorithm (COARE) in the Great Lakes ice-hydrodynamic forecast model, which will be used in the next generation GLCFS, as well as in the forecast model at the Center for Operational Oceanographic Products and Services (CO-OPS). Results of hydrodynamic modeling will serve as a basis for model skill assessment and ultimately improve the development of operational HAB and hypoxia forecasts for Lake Erie, to be incorporated into the GLCFS. Data products will be integrated into the Great Lakes Hydro-Climate Dashboard and shared through the GLCFS framework. The improved GLCFS, and operational GLOFS, provide nowcasts and forecasts of currents, temperature, ice cover, and water levels to the public and resource managers to inform the use and management of the Great Lakes.

Focus 3b. Climate and weather forecasts

Objective 3b.1: Advance regional climate and Earth system modeling to aid decision-making (core)

Potential PIs: CIGLR – Fujisaki-Manome, Godwin, Fraker, Dick (UM); Mantha (MSU); GLERL – Lofgren, Chu, Rowe, Wang

We will continue our collaborative efforts with GLERL to develop the Great Lakes Earth System Model (GLESM), to expand the range of climate variability and impact scenarios that can be simulated. Development of individual modeling components, including the Great Lakes Ice-Circulation Model (GLIM), the unstructured grid Finite Volume Community Ocean Model (FVCOM), a Great Lakes regional implementation of the Weather Research and Forecasting (WRF), and the Process-based Adaptive Watershed Simulator (PAWS), have laid the groundwork for a fully coupled model with two-way interactions among the atmosphere (WRF), hydrology (PAWS), lake dynamics and ice (FVCOM-based GLIM), and the lower trophic level ecosystem (nutrient-phytoplankton-zooplankton-detritus model, NPZD). The ultimate goal of this research area is to produce an integrated model of the Great Lakes physical environment, including the atmosphere, hydrologic system, 3-dimensional lake dynamics, and lake ice dynamics, that couples physical models to ecosystem models for applications to understanding and forecasting hypoxia, harmful algal blooms, and fisheries. This approach also holds great promise for coupling to watershed models in order to address questions of how combined effects of climate change and land use will affect nutrient loads and lake ecosystems.

CIGLR will continue development and analysis of individual models (WRF, PAWS, GLIM, FVCOM), using additional general circulation models (GCMs) as lateral boundary forcing. Analysis of historical drivers of Great Lakes physical conditions will continue by investigating the impacts of teleconnection patterns, including El Niño-Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), Pacific Decadal Oscillation (PDO), and Atlantic Multi-decadal

Oscillation (AMO). The project will produce a set of dynamically downscaled climate projection models that simulate conditions on a local scale and can be used to guide natural resource decision-making by government agencies (federal and state) and non-profit conservation organizations. Model results will be disseminated using the Great Lakes Hydro-Climate Dashboard. In previous years, the downscaled models were used by numerous partners and stakeholders, including the USGS, Michigan Department of Environmental Quality, and Michigan Department of Natural Resources to predict future changes in lake and stream temperatures and potential spread of aquatic invasive species; by Ducks Unlimited, MDNR, and others to explore future changes in weather severity and implications to food availability and migratory behavior of dabbling ducks; by USDA Forest Service to assess forest ecosystem vulnerability across northern WI and upper MI; and by the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) to aid in adaptation planning for species that tribes harvest and GLIFWC regulates.

Objective 3b.2: Improve forecasts of extreme events in the Great Lakes and their connection to large scale atmospheric circulations (core)

Potential PIs: CIGLR – Fujisaki-Manome, Jablonowski, Pettersen (UM); Chen (MSU); GLERL – Fry, Chu, Lofgren

Extreme weather and water events such as extreme precipitation, flooding, winter storms, high waves, and extreme cold weather are expected to become more frequent due to climate change. CIGLR will work to improve the predictability of such extreme weather events from sub-seasonal to seasonal scales in order to mitigate their impact on Great Lakes communities and residents. This goal will be achieved by (i) advancing our understanding of how the occurrence of extreme events is connected to large-scale atmospheric circulations such as teleconnection patterns and (ii) apply downscaling models as described in *Obj. 3b.1*. We will advance forecast models for such extreme events by testing and verifying model coupling techniques for Great Lakes applications. For example, we will continue to improve Great Lakes weather, lake, and ice forecast models by the 'loose-coupling' technique, in collaboration with NOAA-GLERL, the National Weather Service Weather Forecast Office, and NOAA's Earth System Research Laboratory. Furthermore, we will test and evaluate the coupled model system for the Great Lakes region using the Earth System Modeling Framework (ESMF) to couple the hydrodynamic-ice model based on FVCOM-Ice and a weather model based on FV3. This will set a solid basis for Great Lakes' future integration into the Unified Forecast System. This project will provide operational forecasters improved lake-effect snowfall, precipitation, and ice forecasts guidance, as well as increased capacity of coupled modeling systems for better prediction of extreme events.

Objective 3b.3: Improve ice modeling for the Great Lakes and Arctic Ocean (core)

Potential PIs: CIGLR – Fujisaki-Manome, Beletsky (UM); GLERL – Wang, Chu, Lofgren; Partners – Notaro (UW-Madison)

This project advances modeling techniques in predicting sea ice, lake ice, and ecosystem dynamics. In the Arctic Ocean, CIGLR will continue ongoing efforts to improve understanding of ocean/sea ice circulation and ice-ocean-ecosystem dynamics using modeling techniques (i.e., Coupled Ice-Ocean Model (CIOM), Princeton Regional Ocean Forecast (and Hindcast) System's (PROFS), and Physical-Ecosystem Model (PhEcoM). Climate variability scenarios in the Pacific Arctic Region (PAR) will be processed and the key climate patterns that impact the physical and

ecological oceanography in the region, such as the Arctic Dipole Anomaly, will be identified. This study will have a broad impact on 1) understanding the ice-ocean-ecosystem dynamics that explain the high primary productivity region in the Arctic Ocean, seasonal phytoplankton blooms, and interannual variability, and 2) ice edge changes due to climate variability and the subsequent impacts on primary and secondary productivity. The modeling results will be shared with research scientists conducting RUSALCA field observation projects and an optimal sampling strategy will be designed to improve coverage. The modeling framework for the Bering-Chukchi Seas marine observatory is available on the NOAA Climate Program Office Arctic Research Program website: http://www.arctic.noaa.gov/.

Because Arctic ice-ocean-ecosystem models bear features similar to temperate ice-covered waters, the Bering Sea ice-ocean-ecosystem models developed for this project can be applied to the Great Lakes Earth System Model (GLESM). The modified Finite-Volume Community Ocean Model (FVCOM) for Great Lakes ice circulation (FVCOM-ice), an individual modeling component of GLESM, will be used to investigate the lake-ice system response to climate variability in the Great Lakes. Although ice dynamics and hydrodynamics in large freshwater lakes have many similarities to those in coastal oceans, they also have distinct features, such as absence of brine in ice and inverse thermal stratification in winter. Thus, we will also aim to improve the models by advancing and implementing our understanding of the characteristic processes of ice and water mixing in freshwater systems. FVCOM-ice will be validated with novel ice observations collected in the Great Lakes. These models underpin forecasts that provide decision makers with tools to aid in protecting the Great Lakes ecosystem and the public. The Great Lakes Ice Atlas, publicly available at https://www.glerl.noaa.gov//data/ice/atlas/index.html), will be updated each year and seasonal ice projections will be developed. Seasonal ice projections will continue to be provided to end users in search and rescue operations, navigation (i.e., commercial shipping), and recreational/subsistence ice fishing.

Focus 3c. Ecosystem and water quality forecasts

Objective 3c.1: Develop advanced predictive models of harmful algal blooms to improve forecasts, prepare water users, and inform policy (emerging)

Potential PIs: CIGLR – Fraker, Godwin, Denef, Dick (UM); Knuth (Cornell); GLERL – Rowe, Vanderploeg

The CI has played a key role in developing NOAA's harmful algal bloom (HAB) forecasts for Lake Erie. Future model development will focus on: (1) developing individual-based models of phytoplankton dynamics that can be coupled to simulated three-dimensional transport of HABs, (2) coupled biophysical models that produce forecasts of HAB extent and toxicity as a function of management actions to reduce nutrient loading, and (3) incorporating rate measurements and strain-specific knowledge of *Microcystis* to the next generation of ecological and biophysical models.

CIGLR is leading a new modeling effort to develop a biophysical deterministic model to examine relationships between key environmental factors on *Microcystis* blooms. We are updating a previous mass-balance Nutrient Phytoplankton Zooplankton Detritus model to include dreissenid mussels and couple it to the FVCOM hydrodynamics model. We will develop model projections of the extent and intensity of HABs and in-lake phosphorus distributions, and compare projections under various phosphorus loading scenarios. We are also developing

Bayesian regression and network models to understand the link between loading and in-lake nutrients, chlorophyll, and microcystin concentrations.

To facilitate co-design of modeling and data-products that are useful to end-users such as public water systems, CIGLR's Stakeholder Engagement Specialist will work with GLERL PIs to identify and assess user needs related to HAB data and information for decision making, and develop effective mechanisms to disseminate CIGLR and GLERL HAB research tools and forecasts. To do this, we will build on previous work in which we have conducted focus-group workshops with the Lake Erie fisheries community to introduce NOAA's HAB forecasting tools and follow up with additional studies to receive feedback on how the tools are being used for decision-making by various stakeholder groups. Through the same process of co-design, we will identify HAB informational gaps and research needs, and introduce NOAA's HABs forecasting products.

Objective 3c.2: Hypoxia forecasts: Modeling dissolved oxygen for public water systems (core)

Potential PIs: CIGLR – Godwin, Beletsky, Johengen (UM); GLERL – Rowe

Lake Erie provides drinking water to 11 million people through > 30 public water systems. Strong water quality differences exist between surface and bottom water during summer stratification in the central basin of Lake Erie. Weather-driven dynamics during stratification can cause water intakes to be alternately exposed to surface or bottom water, requiring public water systems to adapt treatment processes to changing raw water quality. In particular, bottom water in summer is usually hypoxic, with a lower pH and elevated iron and manganese concentrations that require adjustments to the treatment process. The goal of this project was to give public water systems advance warning of lake circulation events that are likely to cause changes in raw water quality at their intakes through the development of a dissolved oxygen forecast model for Lake Erie. The Experimental Lake Erie Hypoxia Forecast is now being prepared for transition to operation at NOAA. CIGLR will assist with running the model at GLERL to assess and validate the operational version. CIGLR is contributing primary research on this topic using biogeochemical observing systems, survey sampling, and experiments to characterize central basin oxygen demand rates and the release of manganese and other elements under hypoxia[33,34]. The parameters and rates from this primary research will be used in the next generation of biogeochemical and water quality models.

Objective 3c.3: Land use: Forecasting tipping points in Great Lakes water quality (core)

Potential PIs: CIGLR – Basso, Hyndman, Lupi, Garnache, Ostrom, Stevenson (MSU); Carrick, Graziano (CMU); GLERL – Rutherford, Mason, Stow

Since 2011, the Tipping Points team has identified tipping points in watershed land use that affect the health of Great Lakes tributaries and nearshore areas. Based on extensive research, the team developed and published a Tipping Points and Indicators Planner support system – an online program for use by extension specialists, coastal managers, and consultants who work with land use commissions and watershed planning committees. This tool helps watershed leaders identify land-based activities that lead to increased nutrient loading, runoff, and nonpoint source pollution that threatens the sustainability of ecosystems in their watershed, as well as policy and management interventions to keep ecosystems from crossing a tipping point and moving to an unstable condition. The goals of this project are to improve and expand the Tipping

Points and Indicators program by (1) incorporating decision making and restoration efforts that occur more locally, at sub-watershed levels where most management take place, and (2) coupling the present biophysical models with extensions to economic models that predict the economic consequences of environmental shocks.

To accomplish goal 1, we will enhance the Tipping Point Planner (TPP) with high-resolution data for nutrient sources in select Areas of Concern (e.g., the Fox River, Saginaw River, and Maumee River AOCs) and with models that relate nutrient sources to multiple endpoints. Specific tasks include identifying the relationships between nutrient loads and ecosystem variables (e.g., water quality, fish productions) and implementing these relationships into the DSS, engaging local stakeholders (e.g., extension land use professionals, consultants, and/or agency watershed officials) in improving the predictions, and training facilitators to employ the DDS for community visioning and planning. The end-product of this project is an improved TPP DSS, again made publicly available (http://tippingpointplanner.org) for use by local stakeholders engaging in watershed planning activities.

To accomplish goal 2, we will link the outputs of biophysical models to inputs for regional economic and planning models. We will focus on two complementary socio-economic models: (1) Economic Impact Analysis for Planning, (IMPLAN), which characterizes primary sectors (e.g., water utilities), but it is not a dynamic model, and (2) Regional Economic Modeling (REMI), which is a dynamic model that includes both a demographic and a fiscal component, but lacks a precise break down of primary sectors. For both models, parameters of water quality (e.g., P-loads, density of harmful algae) will be developed as quantitative functions that lead to reductions in specific sectors, including an influence on 'amenity values'. These impacts on amenity values can then be used to approximate the marginal cost of changes to the bio-physical variables to the sector of the economy identified. Rather than providing exact cost estimates of environmental stress, our objective will be to develop a new framework that links the ecological drivers of tipping points to the human and socio-economic components that drive policymaking in a relative sense.

Objective 3c.4: Improve models to predict changes in Great Lakes recreational and commercial fish populations (emerging)

Potential PIs: CIGLR – Fraker (UM); Bence, Brenden, Robinson (MSU); Galarowicz (CMU); Ruetz (GVSU); Bootsma, Liao (UWM); GLERL – Vanderploeg, Rowe

Climate change has the potential to induce state changes in fish population size, abundance, and geographic distribution. Yet, we lack the models needed to link key aspects of climate variation to lake trophic models and to forecast shifts in fish species of commercial or recreational importance. The goals of this project are to (1) quantify historical variation in key environmental conditions (e.g., lake temperatures, ice-cover), and (2) relate effects of historical and anticipated future environmental conditions on fish population recruitment, mortality, and fishery fleet dynamics. This information will provide the foundation for revising fishery models to incorporate climate influences. The outcomes of this work will serve NOAA's Climate and Fisheries Initiative, which aims to provide a modeling and decision support system to help fisheries adapt to a changing climate.

To accomplish these goals, we will first compile and analyze long-term monitoring data to quantify relationships between environmental drivers and fish populations and fisheries. We also will link the Great Lakes Earth System Model (GLESM, *Project 3b.1*) and the widely used

CSIRO Atlantis ecosystem model, which is a modular modeling framework capable of producing realistic simulations of ecosystem dynamics. We will then (1) conduct model assessment of each model's performance and prediction skills for the period 1993-2015, and (2) conduct probabilistic seasonal projections of regional atmosphere, lake hydrodynamics, food web biomass and fish distributions for 2018-19. We will focus on ecological effects of extreme warm and cold climate scenarios that are associated with global teleconnection patterns. The end products will be the linked WFA modeling system for Lake Michigan, seasonal prediction of regional climate, lake hydrodynamics and thermodynamics, food web dynamics, and fish distributions and movements. These seasonal prediction outputs in both graphic and digital formats will be displayed on the GLERL website and archived in our GLERL computer for users to download. The final WFA modeling system will be run and maintained at GLERL with the seasonal prediction directly linked to NOS's website and will be transferred to NOS and run for seasonal prediction with further funding. Output from FVCOM then serves as input to models of higher trophic levels, which will focus on several species of commercial and recreational fisheries (Chinook salmon, lake trout, lake whitefish, walleye, and yellow perch) that represent a multi-billion dollar industry[25]. Finally, we will also use a trait-based modeling approach to disentangle the effects of warming versus other anthropogenic stressors on fish community change through time[35].

Objective 3c.5: Predict adoption of best management practices and ecosystem outcomes (core)

Potential PIs: CIGLR – Gasteyer (MSU); Irwin, Wilson, Martin, Kalcic, Labarge (OSU); GLERL – Stow, Mason

We now know that the increasing severity and frequency of harmful algal blooms in Lake Erie are the result of both meteorological trends and the agricultural management practices of farmers across the western Lake Erie basin (WLEB)[26]. However, the focus of most forecasting models is on the biophysical as opposed to social or behavioral drivers in the coupled human and natural system. These models could be substantially improved if they more accurately captured human behavior as a driver of ecosystem outcomes. If we want to go a step further and inform decisions designed to offset the negative impacts of climate variation on Lake Erie, we will need to better understand the roles of human behavior, and the ways in which behavior can be altered to create a more sustainable and resilient system. The goal of this project is to integrate human behavioral complexity into biophysical forecasting models to better explain current fluctuations in phosphorus loading so that we can better predict future fluctuations that result from changes in behavior across the landscape.

We will limit our modeling to three best management practices that have shown to be effective at reducing phosphorus loading into Lake Erie[27]: cover crops, subsurface placement of fertilizer, and filter strips. These practices cover the range of potential tools from those focused on avoiding nutrient loss (subsurface placement), to those that control nutrient loss (cover crops), to those that trap nutrients being lost from the field (filter strips). We have preliminary data on farmer baseline and future likely adoption of these practices building on extensive survey research by the project leads. We will leverage this existing data to develop a spatially explicit model of the probability of adoption of each practice for a given spatial unit across the WLEB. A spatial unit (e.g., field, county, etc.) can be assigned a particular probability given certain characteristics of the unit (such as soil type, slope of the field, etc.). These probabilities can then be used to inform scenarios in existing hydrological models (e.g., SWAT) that predict the

movement of phosphorus across the landscape given changes in agricultural land use and management, which in turn can be linked to existing ecosystem models based on phosphorus loading inputs.

Theme 4. Protection and Restoration of Resources
Safeguarding habitats, natural capital, and ecosystem services throughout the Great Lakes

This theme recognizes the strong link between Great Lakes habitat and human physical, economic, and social well-being. The Great Lakes region sustains an economy for some 30 million people and provides the ancestral homeland of 35 federally recognized Indian Tribal Nations. Great Lakes coastal cities face multifaceted challenges including a shifting economic and demographic landscape, climate change-induced extremes in precipitation and lake levels, aging infrastructure, and expanding urban land-use and its impacts. Effective adaptation to these changing conditions has the potential to build resilient and sustainable communities. Habitat throughout the region provides people with a multitude of ecosystem services, including goods such as food and water, services such as flood protection and water purification, and cultural benefits such as recreation and tourism. Many of these services have measurable economic value that has yet to be quantified and accounted for in existing markets. Other services cannot be bought and sold in existing markets: the value of the Great Lakes for climate regulation; the amount you would pay to protect the Great Lakes so that your children could enjoy them in the future; the value of the Great Lakes for mental and physical health.

In 2014, a binational, multi-sector group proposed an approach for understanding and assessing a range of ecosystem services provided in the Great Lakes region in order to help managers set priorities and allocate resources to restore and sustain a healthy Great Lakes ecosystem and economy. The Blue Accounting Report[28] identified nine common regional goals, based on an evaluation of the key binational and regional environmental agreements. In the Great Lakes region, place-based programs such as marine sanctuaries, NERRS sites, and Areas of Concern offer opportunities to address the key threats and issues that will generate tools, techniques, and technologies to help managers restore habitats and improve system resilience. While the proposed work will develop distinct tools and technologies, the project teams will coordinate and share insights related to their methodologies and seek to share data wherever possible. To facilitate the protection and restoration of Great Lakes habitat, their natural and social resources, and the services they provide, CIGLR will focus on 3 research areas for Theme 4: valuation of ecosystem services, habitat protection and restoration, and social adaptation and resilience of coastal communities.

Focus 4a. Valuation of ecosystem services

Objective 4a.1: Quantify the use and non-use values of Great Lakes ecosystem services (core)

Potential PIs: CIGLR – Moore (UM); Lupi, Garnache, Herriges, Stevenson (MSU); Sohngen, Gopalakrishnan (OSU); Steinman (GVSU); Graziano (CMU); Boyer, Price (UWM); Doran (TNC)

As one of the world's iconic geologic features, the Great Lakes provide a vast array of ecosystem goods and services to residents of the region. Yet, few studies have attempted to estimate the economic value of the many goods and services the Great Lakes provide. Of studies that do exist, most focus on use-values of the Great Lakes, such as the value of commercial and recreational

fishing, or the value of water for municipal and industrial uses. But a large fraction of the value of the Great Lakes lies in non-use values, such as options, existence, and bequest values that are not easily captured in existing markets. This objective aims to estimate both use and non-use values stemming from changes in nutrient loadings to the Great Lakes.

We will expand existing water quality production models that link nutrient sources and best management practices to nutrient loads, and then nutrient loads to several ecosystem services that can be measured over a range of spatial scales. Both statistical and process-based models will be advanced with existing and new data. A multi-modeling approach will be used to evaluate the causal basis and predictive capability of the water quality production modeling. This will, in turn, enable us to examine how use and non-use values change with the specific metric used to characterize ecosystem services (e.g., water quality ladder, water clarity, beach fouling, harmful algal blooms, the biomass of individual sport and non-sport fish populations, or a continuous water quality index) and the spatial scale at which they are specified. Surveys will then be fielded to gather information on people's revealed and stated preferences for these ecosystem services. Focus groups, pre-tests and the survey instruments will be used to assess public understanding and compare measures of use and non-use value based on physical measures of nutrients, levels of the water-quality ladder, and other quantified ecological conditions. Total willingness to pay (TWTP) will be deconstructed into use and non-use components. We will then produce a model that predicts changes in use and non-use values with the metrics used to characterize the ecosystem services and the spatial scales at which services are provided, which can then be related to nutrient loads, tradeoffs among management strategies and goals, as well as costs to reduce nutrient loads.

Objective 4a.2: Determine non-monetary values of Great Lakes ecosystem services (core)

Potential PIs: CIGLR – Read, Balzano, Webster (UM); Doran (TNC); Partners – Erickson (NERR)

This strategic objective aims to identify and operationalize a suite of non-economic indicators of ecosystem services (e.g., social, spiritual) that can be incorporated into the Blue Accounting program that is under development by the Great Lakes Commission and The Nature Conservancy.

The project team will recruit a multi-sector advisory group from organizations already engaged in the Blue Accounting program, which will be facilitated by the proposed project PIs, some of whom are members of the Blue Accounting Advisory Committee with close connection with the program and its participants. A systematic review of the extant peer-reviewed literature related to the effects of ecosystem investments on community social and spiritual well-being will be conducted. The material will be summarized and presented in the form of a conceptual model that will include potential indicators. The project team will convene a workshop composed of the advisory group and an invited, multi-disciplinary group of researchers to consider the proposed conceptual model and indicators. The workshop will consider appropriate analytical approaches, sources of data (both those readily accessible as well as those more challenging), and identify three to five useful indicators to consider for a pilot study. Working with the Blue Accounting program team and with the input of the advisory group, who will help identify up to three test cases, the project team will assemble data to compare the pilot indicators across test cases to evaluate their value in supporting regional decision making. The primary outputs of this effort will be a suite of pilot indicators to be considered by regional decision makers – local through federal – for refinement and incorporation into the Blue Accounting program.

Focus 4b. Habitat protection and restoration

Objective 4b.1: Map and monitor ecological and socioeconomic resources for NOAA protected areas (emerging)

Potential PIs: CIGLR – Miller (UM); Klump (UWM); Fitzgerald (Windsor); GLERL – Chu, Ruberg, Rutherford, Leshkevich; Partners – Brody, Gray, Green (NMS)

The designation of the 962-square-mile Wisconsin Shipwreck Coast National Marine Sanctuary in 2021 marked the arrival of the second national marine sanctuary in the Great Lakes, along with Thunder Bay on Lake Huron. Together with pending proposals for additional sanctuaries in the Great Lakes, this presents an opportunity to expand the role of sanctuaries in facilitating scientific research. CIGLR has already established a role in supporting monitoring and science in Great Lakes sanctuaries, having facilitated publication of over a dozen scientific papers on sanctuary research by Regional Consortium partners. We also deployed a buoy and performed monitoring at the Wisconsin sanctuary to provide water column temperature data, which will aid commercial and recreational anglers and other water users, and will feed into NOAA models that forecast water and weather conditions, and will improve understanding of phenomena such as coastal upwelling.

CIGLR will continue to work with NOAA-GLERL, the National Centers for Coastal Ocean Science (NCCOS), and NOAA's Office of National Marine Sanctuaries to characterize existing nearshore resources and provide information needed to develop conservation priorities and identify recreation and tourism opportunities. This work will include ecological and socio-economic assessments and habitat mapping, observing systems deployment and maintenance, and natural and social system research facilitation and execution. We propose to make sanctuaries a focal point for initiatives such as the proposed biodiversity observation network (see *Obj. 5b.1*), promoting sanctuaries as sentinels of environmental and ecosystem change. We will use an existing geospatial framework, the Great Lakes Aquatic Habitat Framework (GLAHF), that has all existing habitat and water quality data available for Lake Michigan including the WI area. GLAHF has also developed an ecological classification system that can be used to identify unique ecological areas and compare those to similar areas within Lake Michigan. These data are currently available in an online viewer (glaf.org) to which additional spatial data and imagery can be added.

Objective 4b.2: Quantifying sociocultural services in National Estuarine Research Reserves (NERR) and NOAA Marine Sanctuaries (emerging)

Potential PIs: CIGLR – Read, Moore (UM), Liesch (CMU), Vail (GVSU); GLERL – Rutherford, Mason; Partners – Brody, Gray, Green (NMS), Kerns, Erickson (NERR)

Some of the most difficult ecosystem services to assess and analyze are those that are not easily measured or quantified, many of which fall under social or cultural services at the individual or community scale, such as sense of place, identity, and the value of local heritage. Yet these sociocultural services are some of the most important and valuable to people[29], influencing individual behaviors and collective decisions. When characterized and studied at the community scale, these sociocultural services can ground-truth more broadly collected data and provide insight into values, behavior and decision-making not otherwise discernible. CIGLR will continue to develop and refine a community level, place-based assessment and analysis protocol

to quantify sociocultural services of National Estuarine Research Reserve (NERR) sites and to analyze and display the richness and variety of these services and social values.

We will use Rapid Assessment Protocol methodologies, employing semi-structured interviews and targeted surveys, to collect and analyze qualitative data within coastal watersheds, focusing on people's connection to nature, leisure time, cultural fulfillment and social cohesion at sanctuary and NERR sites. Qualitative analytical software and a grounded theory analytical framework will be deployed to examine these data, characterize the social and cultural services and measure related social values. Together with more easily quantified ecosystem services, this information will support a more comprehensive characterization of human and community well-being while revealing the rich fabric of human values related to prospective decisions for restoration or protection. Information from this project will be developed into outreach and education material in partnership with NERR and sanctuary staff to best address their community and partner needs. These results will not only support the missions of these place-based programs, but, by providing this baseline, the NERRS would then be positioned to adopt local and sustained sociocultural monitoring through their System Wide Monitoring Program. Piloting an approach to address sociocultural ecosystem services in this manner would ultimately be of benefit to the entire NERR System, National Marine Sanctuaries, National Estuary Programs, and other place-based efforts.

Objective 4b.3: Explore and understand novel habitats and biodiversity within NOAA Marine Sanctuaries (core)

Potential PIs: CIGLR – Biddanda (GVSU); Dick, Sheldon, Kharbush (UM); Chappaz (CMU); GLERL – Ruberg

Time, water, and geologic forces have converged to create underwater sinkholes in Lake Huron, supporting ecosystems that hold value due to their novel biodiversity, potential for drug discovery, and analogy to ancient ecosystems that shaped Earth's geobiological evolution. The presence of such a unique ecosystem in the Great Lakes, and within the Thunder Bay National Marine Sanctuary, provides excellent opportunities for scientific research. However, the distribution of these deep sinkholes and their associated chemosynthetic ecosystems is unknown. While there is geologic and bathymetric evidence for their widespread occurrence, only two have been confirmed. CIGLR will continue to survey known and suspected locations of deep sinkholes within this designated protected area, explore their biological diversity.

Working in partnership with NOAA's Thunder Bay National Marine Sanctuary and NOAA-GLERL, we will continue our systematic interdisciplinary exploration of sinkholes in Lake Huron. This will be done by characterizing the geophysical environments of deep water sinkholes via shipboard multibeam imaging, ROV-based laser scanning, and underwater video. We will also continue to characterize hydrographic conditions, microbial composition and diversity, and sediment geochemistry. These studies will identify locations of sinkhole ecosystems and determine how the unique communities respond to changes in water level, water clarity, and temperature associated with environmental and climate change. Overall, this work could have implications for conservation, including potential expansion of the sanctuary.

Focus 4c. Social adaption and resilience of coastal communities

Objective 4c.1: Climate adaptation: Enhancing risk communication to prepare for climate variation (core)

Potential PIs: CIGLR – McComas (Cornell); Lemos, Norton (UM)

Successful engagement of coastal community members in efforts to build resilience in the face of climate variation entails not only acceptance and support of proposed actions but also sustained participation over time. Even the best efforts to build resilience will fail if residents do not adopt the proposed actions or participate in the process due to a lack of trust in risk managers. The goal of this project is to investigate factors encouraging or discouraging coastal community decision makers from adopting proposed actions and participating in the decision-making processes related to preparing for climate variation. The work will focus on how key outcomes are influenced by trust in the risk managers, perceived fairness of the public engagement process, beliefs about variation in climate and weather, and self- and collective-efficacy in the face of proposed actions.

CIGLR will lead multi-method case study approaches over two phases of data collection. Phase I employs qualitative techniques to characterize stakeholder interaction in one or more communities, chosen with input from CIGLR partners and NOAA collaborators. During these site visits, researchers will conduct semi-structured interviews with local officials and leaders. These site visits and interviews will help to uncover possible unidentified factors deemed important for enhanced adoption and sustained participation in planning and implementation. In addition, site visits will facilitate the collection of documents and other archival evidence, which will help characterize the community and any preceding interactions between risk managers and community residents. Phase II entails a community survey to better understand and predict factors that influence community members' trust in risk managers, satisfaction with the participation process, intentions to adopt or support risk mitigation behaviors, and willingness to continue to participate. Experimental techniques will help to test the influence of different methods of framing risk information on dependent variables. Statistical analysis will examine the consistency and variance of responses by community. Resulting products will provide detailed insight into what encourages and discourages adoption of proposed actions and sustained community participation in the preparation process for climate variation impacts in the Great Lakes.

Objective 4c.2: Support coastal resilience to changing water levels (core)

Potential PIs: CIGLR – Fujisaki-Manome, Beletsky, Gronewold, Norton (UM); Steinschneider (Cornell)

The International Joint Commission's lake level management plan for Lake Ontario, dubbed "Plan 2014," aims to restoring more natural lake level variability to promote ecosystem health. Communities along the southern shore of Lake Ontario in New York State are concerned that increased variability in lake levels will increase shoreline erosion during wet periods and inhibit lake access during dry periods, and that these dynamics may worsen with climate variation. These increased dynamics could, in turn, prompt contentious debates about whether it would be prudent to continue hardening shorelines with armoring, to explore the potential for managed retreat, or to adopt some hybrid policy approach in between. These policy decisions will require credible predictions of potential future lake level fluctuations. Plan 2014 also includes an innovative adaptive management plan that is being implemented with the support of the Great

Lakes-St Lawrence Adaptive Management (GLAM). The goal of this project is to work with GLAM and south shore communities, such as the Wayne County (New York) Soil and Water Conservation District, in order to provide realistic lake level scenarios under a wide range of climate futures that can be used to both plan for local adaptations, and support adaptations in Plan 2014.

We will develop a lake-level management model that replicates Plan 2014 operations and explore lake-level variability under a range of net basin supply scenarios. These scenarios will be driven by a publicly-available, large (234-member) ensemble of downscaled climate projections from the Coupled Model Intercomparison Project Phase 5 in order to explore the effects of future climate uncertainty on the possible range of lake levels. This effort will supplement past assessments of Plan 2014, which only tested the plan under four scenarios of future climate. We will develop and use a basin-scale rainfall-runoff model and net evaporation model to develop net basin supply scenarios for Lake Ontario from the ensemble of climate projections. We will use Bayesian methods to propagate uncertainty from these hydrologic models into scenarios of net basin supply. Finally, using available lake-level data from buoys along the southern shore of Lake Ontario, will develop probabilistic models of actual lake levels based on modeled lake levels. In this way, uncertainties from future climate, hydrologic modeling, and spatial lake level heterogeneity will be propagated into the scenarios of lake levels. Working with GLAM and south shore community users we will use the resulting large, probabilistic ensemble of potential future lake levels to develop scenarios that report on relevant metrics for the community, such as the frequency and duration of extreme high and low lake-level events, or anticipated number and magnitude of shorter-term episodic events (e.g., storms and seiches).

Objective 4c.3: Understand and formulate strategies to address the inequitable impacts of flooding on communities throughout the Great Lakes (emerging)

Potential PIs: CIGLR – Fujisaki-Manome, Beletsky, Hughes, Gronewold, Seelbach, Norton (UM)

There are persistent inequalities in the distribution of environmental risks and ecosystem services in Great Lakes communities, including flood risk and flood protection. Policy and planning innovations that promote a more systematic approach to flood management will serve as a foundational mechanism for addressing inequity in the Great Lakes. This project will assist the GLSL Cities Initiative and its members in developing strategies to build capacity and strengthen local and regional coastal resilience plans. Building on surveys conducted by the GLSLCI, we will (1) map identified needs to existing resources and partnerships; (2) identify existing resource gaps and recommend approaches to remedy them; (3) share local success stories among local, state, and federal actors; (4) facilitate development of resilience implementation strategies by member cities; and (5) facilitate integration of Great Lakes cities into emerging regional, coastal resilience “communities of practice.”

More broadly, we will develop new knowledge of how and where flood management decisions are made in the Great Lakes, working with partners and stakeholders, to identify organizations involved in flood management; understand the relationships between those organizations; and identify the functional and geographical boundaries of these organizations and relationships. Decision making authority and responsibilities for flood management are typically divided within and between local units of government, each of which may have very different priorities and capacities. In addition, local decisions are guided in part by resources and directives provided by state and federal governments, and infrastructure is often managed regionally.

Decisions about flood management are likely to be disconnected from other policy and planning areas that have implications for flooding, such as watershed planning, housing, land use planning, and economic development. Flood recovery and reinvestment policies are often based on assessed home values, which are shaped by broader patterns of land-use planning and capital access outside the sphere of stormwater management and can exacerbate inequalities following a stormwater flooding event. Better understanding the governance landscape and institutional challenges will allow us to identify opportunities for greater attention to and investment in low-income and historically marginalized communities.

Objective 4c.4: Coastal management: Local planning for resilient communities (emerging)

Potential PIs: CIGLR – Norton, Read, Gronewold, Lemos, Johengen (UM); Shriberg (NWF); McGrath (TNC); Partners –Meadows, Xue (MTU); GLERL – Frye

With prior support from NOAA and the Michigan Coastal Zone Management Program, a team of urban planners, natural resource scientists, and coastal engineers at UM, Michigan Technological University, and the non-profit planning firm LIAA (Land Information Access Association) recently completed a collaborative, community-engaged research program with selected Great Lakes coastal communities in Michigan to develop planning techniques using "off-the-shelf" data and analytical methods. These techniques have been designed so that coastal localities can adapt them to provide more robust coastal area management analyses in their master plans and then to implement those plans through various land management tools. Practice-oriented results from this work have been published on-line in the form of technical guidance materials.

We will continue to extend our work to additional shoreline communities in the Great Lakes states, and possibly the Province of Ontario, to explore how local attitudes and willingness to manage shoreland development vary across state lines and shoreline dynamics. Work conducted to date has advanced our understanding of how coastal localities in Michigan along the shores of Lakes Michigan and Huron view their responsibilities and authorities to more intentionally manage near-shore Great Lakes. However, it is not clear how well this knowledge translates to other states with different institutional arrangements and other lakes with different physical dynamics. Because this approach requires the collaboration of community partners, the final numbers and locations of study localities, and the types of land management efforts engaged (e.g., plan updates, zoning code amendments), will depend on the availability of partner communities. This will be determined in collaboration with NOAA-GLERL and other CIGLR team members who can help expand the sources of data used and further test the robustness of the analytical planning methods developed.

Cross-Cutting Research: Foci that Integrate CIGLR Themes

While much of CIGLR's research involves interactions between themes, several areas are truly cross-cutting; they do not fit neatly within a particular theme and in fact involve strong links between themes.

Focus 5a. Oil spill science

Objective 5a.1: Conduct oil spill research to support the Great Lakes National Center of Expertise (emerging)

Potential PIs: CIGLR – Fujisaki-Manome, Beletsky, Godwin (UM); Moerke, Sarda (LSSU); GLERL – Wang, Chu, Mrozka, Rowe

Given the prevalence of crude oil transport and the unique characteristics of Great Lakes hydrology and ecosystems, oil spills pose serious threats to life and water of the Great Lakes. However, most of the scientific literature on ecological impacts of crude oil comes from the oceans, and little data are available from freshwater systems or the Great Lakes[36]. CIGLR will conduct research to fill these gaps and support the new United States Coast Guard (USCG) Great Lakes National Center of Expertise (GL NCOE) for Oil Spill Response and Research. This work will focus on the fundamental science, as well as development of technologies and modeling tools that are specific to the freshwater environment, where water density, ice characteristics, circulation patterns, and ecosystems are different from those found in salt water. The specific goals of this work will include (1) evaluation of existing oil spill models including the General NOAA Operational Modeling Environment for applications the Great Lakes; (2) identification of gaps in our ability to predict oil spill trajectories in the Great Lakes and development of strategies to address these gaps; (3) development of scenarios for oil spills in the Great Lakes and model simulations project impacts under these scenarios; (4) determination of potential impacts of ice cover on oil spill trajectories through understanding of oil movement under ice, ice breaking, and wave-ice interactions; and (5) research on the biogeochemical fate of hydrocarbons in freshwater environments, their impact on ecosystems, and advanced technologies for bioremediation. CIGLR will facilitate collaboration between NOAA, the USCG, and regional partners by organizing workshops and working groups. Overall, this research will fill key knowledge gaps in the science of oil spills in freshwater systems and will enhance our capacity to respond to oil spills and mitigate their ecological impacts.

Focus 5b. Integrated observing, science, and modeling

Objective 5b.1: Develop a multi-scale biodiversity observation network (emerging)

Potential PIs: CIGLR – Godwin, Dick, Chaganti, Johengen, Fraker (UM); Rudstam, Sullivan, Watkins, Greene (Cornell); Fisk (Windsor); GLERL – Vanderploeg, Rutherford, Mason, Vander Woude

We plan to fill critical gaps in the science and management of the Great Lakes by creating a biodiversity observation network that uses complementary technological approaches to understand various dimensions of biodiversity. Part of the rationale for conserving, monitoring, and studying biodiversity in marine and Great Lakes ecosystems comes from the fact that biodiversity supports ecosystem functions and critical services, but this relationship has not been quantified within the Great Lakes. CIGLR aims to establish a new biodiversity observatory that will address interconnections among (i) dynamics of pelagic habitats (“lakescapes”), (ii) biodiversity across the tree of life, (iii) movement of fisheries species, and (iv) important ecosystem functions. A key innovation will be the degree of integration across multiple technological approaches featured by NOAA, which extend from high-throughput sequencing and bioinformatics to telemetry for fish populations to mapping large-scale biogeographic patterns measured by satellites. This integration will allow us to examine impacts of multiple stressors and test hypotheses about biodiversity and ecosystem function, which are emerging areas in marine biodiversity but remain understudied phenomena in the Great Lakes. Partners will include GLERL, GLOS, Great Lakes CoastWatch node, NOAA National Marine Sanctuaries, Great Lakes Acoustic Telemetry Observation System, and the Cooperative Institute

for Climate, and Ocean and Ecosystem Studies. The outcomes from the observatory would be co-designed with partners and regional stakeholders. It will include data portals that build upon and connect existing databases (served by IOOS, MBON, ATN, NCBI, and others), a dynamic habitat classification framework operating in near-real time, a genomic observation network connected to environmental data and remote sensing, acoustic telemetry observations targeting understudied juvenile stages, and syntheses of biodiversity and ecosystem functioning using both historical data and emerging technologies. Benefits of this work include supporting binational fisheries management; enhancing monitoring programs with new methods to observe ecological status, trends, and shifts over time; advancing interoperability of different technological approaches; and improving fundamental understanding of how Great Lakes biodiversity supports ecosystem functions and responds to stressors. This project leverages observing technologies to advance the science of ecosystem dynamics, and will inform ecological modeling effort, thus it cuts across three themes.

Objective 5b.2: Catalyze a systems approach to integrating observing, modeling, science, and policymaking (emerging)

Potential PIs: CIGLR – Godwin, Fraker (CIGLR); Shriberg (NWF); Doran (TNC); Fisk (Windsor); Sterner (UMD), Dick, Hughes (UM); Lodge (Cornell), McKay (Windsor), GLERL – Ruberg, Lee; Partners – Paige (GLOS)

Massive streams of physical and biological data are now available from a distributed network of buoys, autonomous gliders, environmental sample processors, satellites, and citizen science efforts that are deployed and supported by numerous entities and agencies across the Great Lakes. While these data streams present exciting new opportunities for detecting and predicting changes to the Great Lakes system, synthesizing this data, coordinating observing with experimental and modeling efforts, and translating this scientific research into actionable information products for society remain as grand challenges. CIGLR plans to play an explicit and intentional role in meeting these unmet challenges by holding a series of summits and working groups with key scientists, engineers, modelers, stakeholders, and policymakers in order to (1) co-design research questions; (2) identify and address gaps in observing data and opportunities for coordinating observing systems; (3) identify and implement opportunities to use data science methods, including machine learning and artificial intelligence, to address research and policy questions; (4) identify critical gaps in modeling capabilities, both in terms of poorly defined parameters and processes that can be addressed with scientific research as well as needs for model development; and (5) develop strategies for translating research into societally relevant products that support policymaking (see the *V. ECO Program, "Engagement"* section below).

Focus 5c. Data science and management

Objective 5c.1: Develop bioinformatics infrastructure for environmental 'omics of the Great Lakes (emerging)

Potential PIs: CIGLR – Dick, Denef, Duhaime (UM), Chaganti (CIGLR), Lodge (Cornell), Heath, McKay (Windsor), Newton (UWM), Sheik (UMD); GLERL – Errera

Full deployment and realization of the potential of new 'omics technologies has been thwarted by challenges in translating the vast and complex data produced into understanding and

actionable knowledge. There is no dedicated database or analysis pipeline for such data, and current databases and analytical tools require inaccessible software and associated expertise. The lack of a dedicated database increases the time and computational resources required for even simple queries, such as determining the abundance of toxin-producing cyanobacteria at different stations across a field season. To address these limitations, CIGLR has started to develop a "next-generation" database capable of synthesizing complex environmental and 'omics data, which is accessible to a wide range of scientists and water quality professionals. Such a database will not only ensure the effective storage and dissemination of 'omics data, it will facilitate studies of Great Lakes biological communities and their interactions with the environment. The database will define networks of relationships between aquatic organisms, genes and metabolic pathways and their expression, and environmental processes and conditions. This database will be applicable to any environmental 'omics or eDNA datasets on the Great Lakes. It will be developed in collaboration with the NOAA 'Omics Working Group and to address the objectives and milestones within the NOAA 'Omics Strategic Plan. We will also work with GLOS to assure compliance with existing data standards such as those of the Marine Biodiversity Observation Network and the Darwin Core. The main product will be a publicly-available yet secure data portal website that will serve as an interface for querying, analyzing, and visualizing the data. This database will be updated with additional information and data as they are made available (or generated). Ultimately, this capability will enable meta-analyses and leverage growing temporally- and spatially-rich datasets for the development of predictive models. These downstream products will be of direct use by modelers as well as stakeholders such as drinking water intake managers and policymakers.

Objective 5c.2: Advance data science for Great Lakes research (emerging)

Potential PIs: CIGLR – Chaganti, Fujisaki-Manome, Duhaime, Wiens, Violi, Jablonowski, Jagadish, Gronewold (UM)

With the exponential growth of data being collected from observing systems and new technologies such as 'omics, the science of data analysis and management has become crucial to optimize the knowledge and value gained from Great Lakes research and monitoring. In the next cooperative agreement we plan to intensify our effort to employ and develop cutting-edge data science and management methods. This effort will be supported through collaboration with data science experts in the CIGLR Regional Consortium, including the Michigan Institute for Data Science (MIDAS), whose mission is to enable the transformative use of data science and artificial intelligence (AI) in a wide range of research disciplines to achieve lasting societal impact (see letter of support by MIDAS Director H.V. Jagadish, Appendix 5). This partnership will involve dimensions of training, recruiting, and collaborative research. MIDAS will provide training opportunities, starting with an environmental data science boot camp and followed by workshops on (i) machine learning, (ii) coding, (iii) high performance computing, and (iv) geostatistics. MIDAS will facilitate hiring of data science, artificial intelligence, and machine learning postdocs and staff through the postdoctoral fellows program. Finally, MIDAS will facilitate collaborations with data scientists via its diverse scientific network of computer scientists, environmental scientists, and biologists.

CIGLR's data science efforts will include both advancing the science of AI and machine learning (e.g., developing and improving algorithms), as well as the novel application of data science and AI to scientific problems in the Great Lakes. For example, Drs. Chaganti, Duhaime, and Dick will use machine learning for the analysis of massive 'omics datasets, drawing on the expertise

of Drs. Wiens and Violi for applying machine learning to microbiomes and other omics datasets. Dr. Gronewold will apply AI, machine learning, and Bayesian analysis tools to improve water level forecasts based on climatic and hydrological inputs. Drs. Fujisaki-Manome and Jablonowski will apply and develop AI and machine learning approaches to forecasting Great Lakes weather, lake-effect snow, and extreme events.

Objective 5c.3. Support data management for the Great Lakes Common Technology Agenda (core)

Potential PIs: CIGLR – Bratton (LimnoTech), Johengen (UM); GLERL – Mason; Partners – Paige (GLOS)

CIGLR will continue to play an important role in data management and data submissions to the National Centers for Environmental Information (NCEI) in coordination with the GLERL Data Manager. CIGLR will develop and maintain web interfaces for data products, including applications for dynamically updated real-time data visualizations and web pages; design and implement data processing workflows and applications; perform data management related to ecological monitoring programs, buoy systems, and autonomous vehicles; assist with visualization, analyses, and quality control; and develop data management best practices.

V. ECO Program - Engagement, Career Training, and Outreach

CIGLR's Engagement, Career Training, and Outreach (ECO) Program facilitates the transfer of Great Lakes research and knowledge into actionable science. With financial support from the University of Michigan and NOAA-GLERL, CIGLR strives to achieve 3 goals through the ECO Program:

Engagement – *Support 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.

Career Training – *Promote a skilled and diverse workforce* by providing career training for undergraduates, graduate students, and postdoctoral fellows who will become the next generation of Great Lakes and NOAA scientists.

Outreach – *Advance environmental literacy* by communicating the value, importance, and usefulness of NOAA's Great Lakes research to the general public at local, state, and regional levels.

The University of Michigan has committed $3.6 million in cost-share funding over the next five years, in part to support CIGLR's ECO Program (*Attachment A. Budget narrative*). ECO Program funding will also come from NOAA-GLERL, which has historically provided ~$100K annually in Task IB funds to support student fellowships and the Great Lakes seminar series. In addition, individual CA research projects (Task II/III) are all required to have a science translation component and encouraged to include postdoctoral and student support in their budgets.

The ECO Program will be implemented by CIGLR's Program Manager, with support from the CIGLR Communications Specialist, CIGLR Engagement Specialist, and guidance from the CIGLR Director. The sections that follow detail activities to achieve each of the ECO Program goals.

Engagement – *Supporting Informed Policy and Decision Making*

CIGLR will work 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. CIGLR aims to take a leadership role in guiding the wise management and protection of the Great Lakes by translating research findings, providing NOAA's tools and data products, and identifying critical research needs to Great Lakes decision makers. Our **legislative engagement** activities will target appropriators and decision makers from the following offices: Great Lakes and St. Lawrence Cities Initiative, Michigan Office of the Great Lakes, Conference of Great Lakes and St. Lawrence Governors and Premiers, Great Lakes Congressional Task Forces, U.S. EPA Great Lakes National Program Office (GLNPO), and the International Joint Commission (IJC). At the Federal level, we will focus on success stories of projects from the Great Lakes Restoration Initiative (GLRI) to advocate for continued legislative support for this program. Our **stakeholder engagement** activities will target resource managers and others who rely on our research tools and products for decision making, with the goal to facilitate the co-production of research outcomes. Stakeholder engagement will be implemented as part of our research programs focused on harmful algal blooms, hypoxia, ice and snow forecasting, oil spill response, and real-time observations.

To accomplish our engagement goals, CIGLR will collaborate with private-sector partners in the Regional Consortium (The Nature Conservancy, and the National Wildlife Federation Great Lakes Regional Center) and supporting initiatives (Great Lakes Commission, International Joint Commission) who represent the strongest advocates for science-based decision making in the Great Lakes. In addition, we will work with other CI Directors to share the importance of our work with NOAA on Capitol Hill, at the Department of Commerce, and in the Office of Management and Budget.

Specific engagement activities within the ECO Program include:

- Great Lakes policy engagement. CIGLR and our Regional Consortium members will engage with local, state, and Federal policy makers at several levels and with a variety of methods. First, we will provide elected officials with the information they need to support decisions, respond to constituent concerns, and understand critical research needs in the Great Lakes. The Policy Engagement section of the CIGLR website provides Michigan legislators with information on Great Lakes issues that impact their districts and what CIGLR is doing to address them. In addition, we will hold briefings, demonstrate technology and research methods, and fulfill information requests for Congressional members and their staff. Second, we will communicate with policy makers via written letters and phone calls when pending legislation on the Great Lakes, urging them to consider science in their decision making and highlighting the economic benefit of protecting and restoring Great Lakes ecosystem services. Third, CIGLR will actively provide input to the International Joint Commission (IJC) as members of Participate IJC, an online democracy forum for contributing to the assessment of progress by U.S. and Canadian governments under the 2012 Great Lakes Water Quality Agreement. Fourth, we will engage with partners and regional organizations to align research, policy needs, and funding initiatives. For example, we will leverage the expertise, experience, and network of the National Wildlife Federation, a CIGLR Regional Consortium member, to engage with the Healing our Waters coalition to identify research and policy priorities for future funding needs. Finally, we will facilitate interactions between scientists, stakeholders, and policymakers to identify policy-relevant indicators in order to assess and illustrate tangible outcomes. These goals will be advanced through CIGLR partner programs, including targeted summits, working groups, and placement of postdoc and graduate student fellows with NGO partners. We will work closely with the University of Michigan's Federal Relations for Research office in all of our policy engagement activities, including receiving guidance on critical topics of interest to legislators.
- Stakeholder engagement. Using a collaborative research approach, we will engage end-user stakeholders in the co-design of research that will lead to socially useful research products. Our research teams will include social scientists that use social science methods such as focus groups, interviews, and surveys to facilitate researcher engagement with stakeholders, with the goal of co-designing research from project development to product distribution. This approach will include assessing end-user information needs and decision-making processes, generating recommendations for research product development based on those needs, and evaluating the usability of research product prototypes (e.g., water quality forecasts for municipal water intakes, online visualizations for charter boat captains and other mariners, and ice forecasts for lake carriers). Research teams will use this information to tailor their products to stakeholder needs to support sustainable resource management in the Great Lakes. Throughout the process, we will develop products such as webpages, fact sheets, and

videos to effectively communicate research results to stakeholders. Primary areas for research co-design with stakeholders include decision support tools for harmful algal blooms, ice forecasting, visualization of real-time observations, and oil spill modeling and response.

Career Training – *Promoting a skilled and diverse workforce*

CIGLR will continue the highly successful career training program that has a proven track record for producing Great Lakes and NOAA scientists and professionals. Along with NOAA-GLERL, our Regional Consortium members, and the University of Michigan, we provide NOAA-mission related research experience and career training to undergraduates, graduate students, and postdoctoral research fellows. Since 2008, we have provided research training to more than 500 students and postdocs, 249 of whom were awarded student or postdoctoral fellowships. CIGLR students, postdocs, and staff progressed to GLERL positions (i.e., federal hire or government contractor) 8 times over the same period, fulfilling the program's goal of producing the next generation of NOAA scientists in the Great Lakes. Five of the federal hires, Drs. Ashley Elgin, Eric Anderson, Dan Titze, Andrea Vander Woude, and Mark Rowe advanced from CIGLR postdoctoral fellow or staff positions to be GLERL principal investigators.

The 10 Regional Consortium universities collectively offer 72 M.S. and Ph.D. programs that are relevant to NOAA's goals and the training of the next generation of Great Lakes scientists. These include degrees in the biological sciences (e.g., ecology, genomics), physical sciences (e.g., limnology and oceanography, atmospheric science, geology), social sciences (e.g., water policy, human behavior), engineering (e.g., naval architecture and marine engineering), interdisciplinary degrees that train students in sustainability (e.g., sustainable systems, policy and planning), and natural resource management (e.g., fisheries & wildlife, conservation biology). In addition, Regional Consortium universities have relevant undergraduate programs that serve as pipelines to graduate programs as well as CIGLR and NOAA programs. This includes Lake Superior State's dedicated undergraduate programs in Fisheries and Wildlife Management, Environmental Science, and Robotics Engineering.

We strive to shape a workforce that is not only skilled in NOAA mission-related research priorities, but also one that is diverse. CIGLR is committed to supporting diversity in an inclusive environment, in alignment with the 2016 Diversity, Equity, and Inclusion (DEI) Strategic Plans issued by the University of Michigan and SEAS. We will continue our ongoing efforts to actively encourage students from groups traditionally underrepresented in the aquatic sciences workforce to participate in our fellowship programs. We accomplish this by advertising fellowship opportunities on key job boards for recruiting diverse students, including the American Indian Science and Engineering Society (AISES) Job Board, Historically Black Colleges and Universities (HBCU) Connect, NOAA Cooperative Science Centers, and the Institute for Broadening Participation. We get advertising assistance from the NOAA OAR Diversity Program Office and through direct contacts at Native American colleges and HBCUs. In addition, we advertise with multiple University of Michigan student organizations such as Multi-Ethnic Student Affairs (MESA), Women in Science and Engineering (WISE), Native American Student Association, and Graduate Society of Black Engineers & Scientists. Asking optional questions on race/ethnicity, gender, and socioeconomic status on fellowship applications allows us to track our success in reaching students from underrepresented groups. In addition, we require an essay describing an obstacle the student has overcome, to help identify students that may be facing unusual circumstances. We will continue to continue to build relationships with

diversity leaders and collaborate with the SEAS Diversity, Equity, and Inclusion Office and the NOAA Equal Employment Opportunity (EEO)/Diversity Program Office to maximize our efforts to increase DEI in Great Lakes science. We will also work with fellowship mentors to develop student and postdoc projects that could benefit from traditional knowledge or cultural perspectives.

Specific career training activities within the ECO Program include:

- Great Lakes Summer Fellowships (8-12 per year). CIGLR will continue to administer the annual Great Lakes Summer Fellows Program, in partnership with NOAA-GLERL. This competitive program places promising upper-level undergraduate and graduate students with mentors from CIGLR, the Regional Consortium, and NOAA. Through this program, students work on substantive research issues covering a broad range of disciplines and undergo a career training program that equips them with the knowledge and skills to become the next generation of Great Lakes scientists.
- Great Lakes Graduate Research Fellowships (2-4 per year). CIGLR will administer a competitive fellowship program that provides career training opportunities to master's or doctoral students that are enrolled at one of CIGLR's Regional Consortium universities. The goals of these fellowships are to: 1) provide training and educational opportunities for students who will become the next generation of Great Lakes researchers, 2) enhance collaborations between CIGLR's Regional Consortium partners and scientists at NOAA GLERL and CIGLR, and 3) increase student retention within the freshwater aquatic sciences.
- CIGLR Postdoctoral Fellowships (3 per year). In addition to supporting postdoctoral positions through Task II research projects, CIGLR will continue to administer a competitive Postdoctoral Fellowship program that is supported by University of Michigan cost share funds. This program provides salary and research support for a postdoctoral fellow to work closely with a faculty mentor at a CIGLR Regional Consortium university on a project of mutual interest to CIGLR and NOAA. The goals of the Postdoctoral Fellowship Program are to 1) expand research training opportunities for postdoctoral scientists working in the area of freshwater sustainability, and 2) enhance collaborations between CIGLR's Regional Consortium partners and PIs at NOAA GLERL and CIGLR.
- Graduate Student Projects and Theses. As research grant funding allows, CIGLR research scientists will continue to serve as advisors for University of Michigan graduate students completing Master of Science (M.S.) research projects or theses. CIGLR will continue to include master's student support in our annual research proposal budgets.
- Project-specific Graduate Student and Postdoc Experience. CIGLR and Regional Consortium members routinely hire undergraduates, graduate students, and postdocs to fulfill CIGLR research project needs. These students and postdocs are mentored by leading research scientists at CIGLR, GLERL, or collaborating institutions/organizations, gaining valuable experience and career training. CIGLR will continue to include student and postdoc support in our annual research proposal budgets. Students will be recruited through university programs (e.g., the Undergraduate Research Opportunity Program at the University of Michigan) and by partnering with NOAA programs such as the Educational Partnership Program (EPP) for Minority-Serving Institutions (MSI) and NOAA Crest.

While CIGLR administers career training programs and activities targeted at undergraduates, graduate students, and postdocs, we recognize that underrepresentation begins prior to college. The fact that NOAA is the least diverse of all federal agencies likely reflects that the Earth and environmental sciences (including ocean and atmospheric sciences) are the least diverse of all STEM fields at all degree levels[37]. The bottleneck is early; there are not enough students from underrepresented backgrounds (underrepresented minority, rural, first generation) in relevant undergraduate fields. Discouragingly, the field has seen no improvement over the last 40 years despite intensive efforts[38]. These considerations highlight the need to focus efforts early in student careers, where the underrepresentation first appears, and to build structures and programs that will recruit and retain students from diverse backgrounds. Thus, CIGLR will work to connect career training and recruitment activities ongoing in NOAA and the Regional Consortium that aim to diversify the field of Great Lakes science. We will build an **integrated pipeline** that starts highlighting the wonder, importance, and career opportunities in Great Lakes science early in students' careers and continues through hands-on career training offered by CIGLR's ECO Program (described above), ultimately producing diverse Great Lakes science professionals. We will focus on programs that follow evidence-based practices including literature that field experiences, hands-on lab and internship experiences, and exposure to career opportunities are important factors in recruiting and retaining students from underrepresented backgrounds.

The integrated pipeline will be developed by leveraging and linking the following existing programs in NOAA and the Regional Consortium to the ECO programs described above:

- **Earth Camp** is a residential summer camp at the University of Michigan that seeks to interest students in Earth and environmental sciences through experiential field and lab activities. Students spend one week on the U-M campus following their 1st, 2nd, and 3rd years in high school. Great Lakes activities include a trip to Sleeping Bear Dunes to study coastal processes and dune formation and a trip the Upper Peninsula to study geological processes involved in the formation of the Great Lakes. CIGLR will collaborate with Earth Camp to support students and develop activities that introduce students to Great Lakes careers at NOAA, CIGLR, and private and non-profit partners.
- **Wolverine Pathways** is a program for recruiting students from the diverse school districts of Detroit, Southfield, and Ypsilanti and preparing them to apply to and succeed at the University of Michigan. Students who participate in this intensive program throughout high school and are admitted to the University of Michigan receive a full scholarship. CIGLR will teach a summer Wolverine Pathways course on The Great Lakes, thus giving students a taste of college while introducing them to the Great Lakes. A pilot version of this class was offered in summer of 2020 by current CIGLR Director Greg Dick; 13 of the 17 students who took the class were admitted to U-M and many are now pursuing NOAA-related degrees.
- **Great Lakes B-Wet (Bay Watershed Education and Training)** is a NOAA environmental education program that provides professional development for teachers and promotes experiential learning experiences for K-12 students. CIGLR will assist B-Wet in recruiting promising students from its K-12 programs (e.g., Earth Camp, Wolverine Pathways) and likewise will advertise its programs through the B-Wet network.

Outreach – *Advancing environmental literacy*

CIGLR's outreach activities are designed to translate and promote NOAA research in the Great Lakes at local, state, regional, national, and international levels. Our key messages relating to CIGLR and our research are formulated using input gathered from CIGLR leadership and principal investigators, and modified as needed for specific target audiences. CIGLR's target audiences include internal and external groups. Internal audiences are SEAS, the CIGLR Regional Consortium, NOAA-GLERL, NOAA CI Administration Office, NOAA GLRCT, and NOAA senior leadership. External audiences include the general public, media, and stakeholders (e.g., resource managers; industry; local, state, and federal government officials; NGOs).

Our continued participation in NOAA communications and outreach groups at multiple levels allows us to coordinate communications and outreach 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 (IS) Communications Group. During monthly meetings with GLERL IS, we coordinate and strategize CI and GLERL communications and outreach activities, share successes and ideas for improvement, and receive guidance on working with the larger NOAA communications network. We also participate in monthly meetings of the NOAA Great Lakes Regional Collaboration Team (GLRCT) Communications and Outreach Working Group, composed of representatives from the CI, NOAA Line Offices, Great Lakes Sea Grant Network, and the Great Lakes Observing System (GLOS). We are also connected with the OAR Communications group and contribute news articles for their monthly newsletter.

At the university level, CIGLR has ongoing relationships with key communications offices at the University of Michigan that increase our exposure from department level up to global scale. We have a well-developed relationship with the science writer and videographer for Michigan News (the university's news and media office), as well as the SEAS Communications Office. Michigan News produces feature stories and videos that are picked up by the press worldwide.

Specific outreach activities within the ECO Program include:

- Great Lakes Seminar Series (8-12x per year). CIGLR will co-sponsor and coordinate the joint CIGLR-GLERL Great Lakes Seminar Series, which brings in regional, national, and international researchers to talk about pertinent new and emerging scientific issues in the Great Lakes. These events facilitate collaborations between researchers, provide an educational opportunity for NOAA and university scientists, and serve as an outreach forum for stakeholders and the general public to attend. Seminars are held at NOAA-GLERL or the University of Michigan and are broadcast via webinar for remote participation. Webinar recordings are available to the public on the CIGLR website and YouTube channel.
- Website. CIGLR remains committed to a strong web presence that facilitates effective science translation, provides visibility to CIGLR and NOAA research, and informs stakeholders, students, and the public about events and opportunities. We use Google analytics to track website usage and popular products. The website is continually updated and under active management. The website address is ciglr.seas.umich.edu.
- Social Media. CIGLR will continue to connect with the public, stakeholders, scientists, and NOAA on social media through our Facebook (@CIGLR.UMich), Twitter (@CIGLR_UM), Instagram (ciglr_um), and YouTube (CIGLR um) accounts. The CIGLR Communications

Specialist holds primary responsibility for maintaining a strong and active presence on social media. CIGLR posts 8+ times per day on Twitter, 3+ times per week on Instagram, and 3-4 times per week on Facebook. We are committed to increasing our social media reach and engagement with our followers.

- News Media. CIGLR will continue to produce press releases on research results and contact Michigan News with media-worthy stories. News articles will be available on the CIGLR website and promoted on social media.
- NOAA OAR Hot Items. CIGLR will contribute Hot Item articles to NOAA OAR promoting CIGLR research results, news updates, and important events. OAR Hot Items articles are accessible only to the internal NOAA community.
- NOAA GLRCT Regional Highlights. CIGLR will contribute articles to the GLRCT for publishing on the Regional Highlights portion of their website. These articles will use CIGLR research results to address one of the GLRCT goals for the region: address regional challenges by connecting people and resources, exchange both national and regional insights that inform action, and improve understanding of and respect for NOAA's broad mission and regional capabilities.
- Quarterly E-newsletters. CIGLR will continue publishing quarterly e-newsletters highlighting CIGLR research, partner interactions, opportunities, and events. Quarterly e-newsletters are directly emailed to a wide audience, including CIGLR Regional Consortium members, NOAA (OAR Communications Office, CI Administrative Office, GLERL), University of Michigan (UM Water Community, SEAS faculty/staff/students), NOAA UM Programs (GLISA, NERRS, Michigan Sea Grant), Great Lakes Information Network (GLIN; listserv), and the CIGLR Executive Board. They are also posted on social media and the CIGLR website. We use analytics included with our newsletter delivery service to track e-newsletter reach and interest.
- Annual News Magazine. CIGLR will continue to publish the annual news magazine *Ripple Effect*, featuring our accomplishments over the year, promoting student opportunities, and highlighting research collaborations. The news magazine will be distributed via direct mail to those who request hard copy, and electronically to the same recipients as our quarterly e-newsletters. Hard copies will also be used to promote CIGLR and NOAA at outreach events.
- Outreach Events. CIGLR will continue to have informational tables at community and university outreach events, and at scientific conferences. Examples of events we will attend include Ann Arbor Mayor's Green Fair, Huron River Day, UM Student Visit Day, UM Green Career Fair, and the Michigan State University Science Festival. Scientific conferences include the International Association for Great Lakes Research (IAGLR) Conference and the Healing Our Waters-Great Lakes Coalition (HOW) Annual Great Lakes Restoration Conference. We will also participate in U-M's Wolverine Pathways program to visit local schools, and continue to coordinate participation in outreach events with other NOAA programs, such as Great Lakes Sea Grant, GLOS, NOAA GLRCT, and NOAA GLERL.
- ECO Funds. To broaden CIGLR's outreach across the Great Lakes, we will provide Regional Consortium members with ECO Funds to support undergraduate or graduate students who incorporate a public outreach or communications component into their work. The student's

education and outreach efforts must highlight NOAA, CIGLR, and Regional Consortium member contributions to research and management of the Great Lakes. Examples include K-12 education activities, community outreach events, public education talks, social media communication, videos, factsheets, newsletters, and magazines.

- Research Project-Related Outreach: All CIGLR research projects will be required to define an outreach component and report on progress in annual project reports. Our ongoing harmful algal bloom (HAB) and hypoxia research in Lake Erie is a prime example of effective project-supported outreach to end users of the data (i.e., drinking water intake managers), which has helped inform and tailor our research products.

VI. Business plan

Organization and operation

The organization and operation of CIGLR will be formatted in accordance with NOAA's CI Handbook[30], which outlines procedures for establishing and maintaining CIs. The University of Michigan will serve as the host and administrative lead for the CI, and bear responsibility for CIGLR operations and management. The CI will be located in the School for Environment and Sustainability (SEAS) and consist of a Research Institute and a Regional Consortium.

CIGLR's organizational structure will follow the long-term plan proposed by CIGLR 10/1/21 and approved by NOAA 2/7/22. CIGLR administrative leadership will consist of a Director, Associate Director, 3 Theme Leads, and a Program Manager who will oversee and manage both the Research Institute and Regional Consortium (Fig. 2). The Theme Lead structure, which was used on an interim basis from 2020 to 2022, mirrors the GLERL science branch structure (Fig. 2) and is exceptionally effective and efficient for communication and coordination of research with GLERL. The Theme Leads serve as partners and points of contact for the GLERL Branch Chiefs. Their parallel disciplinary expertise facilitates effective communication with GLERL Branch Chiefs about ongoing collaborative research, personnel needs, and new funding opportunities. The Theme Lead structure has the additional benefit of improving personnel and project management within the CIGLR leadership team, as the Theme Leads work closely with the CIGLR Program Manager on research plans and proposals, oversight of funded projects, and training and supervision of personnel (see CIGLR Theme Lead Responsibilities below). The effective research coordination and communication achieved by the three Theme Leads is essential given the volume and scientific breadth of collaborative CIGLR-GLERL research, which has grown substantially over the past five years.

Figure 2. CIGLR's administrative structure (right) paired with GLERL's complementary science leadership structure (left), creating an optimal platform for collaborative science planning and execution.

We will also hire an Associate Director, who will assist the Director in representing CIGLR at the highest levels, engage the Regional Consortium, and pursue development of strategic research areas and initiatives. Thus, the Theme Leads will manage the operations of the

Research Institute, while the Director and Associate Director will engage the Regional Consortium, represent CIGLR in its external interactions, and develop high-level research directions and strategies. The specific responsibilities of the Director, Associate Director, and Theme Leads are described below. Given the additional support provided by the Associate Director, the Theme Lead effort will be budgeted at 5% of their time. The Associate Director will be supported at 10% effort, consistent with the 2017 CI proposal, supplemented by incentives from the University of Michigan (e.g., administrative differential, teaching release). The Director will continue to be appointed at 50%. The Program Manager will continue at 100% effort, with duties as defined below. CIGLR administration will be located at both NOAA-GLERL and SEAS to facilitate interactions with university and Federal administrators, PIs, and staff.

Research Institute staff will include Research Scientists, postdoctoral fellows, and research technicians. CIGLR's staff in the ECO Program and the Research Administrator will support both the Research Institute and Regional Consortium (Fig. 3). The Cooperative Institute will form and manage a Regional Consortium consisting of 10 universities and 5 private-sector organizations, supported by major government agency programs and organizations (Fig. 3, and described in Section III). One representative from each Regional Consortium university and private-sector organization is included in the proposed CIGLR organizational structure. The roles and responsibilities of each of these CIGLR entities are summarized below.

Director (Dr. Gregory Dick). Dr. Dick is a full Professor in SEAS and in the Department of Earth and Environmental Sciences, is a renowned aquatic microbiologist, and has considerable experience organizing and leading interdisciplinary research initiatives. Responsibilities of the Director are as follows:

1. Serve as the chief executive officer of the CI; report to the Dean of the School for Environment and Sustainability and lead the CIGLR Council of Fellows and Executive Board.
2. Oversee the administration and budget of CIGLR.
3. Serve as CIGLR's chief science advisor.
    a. Participate in annual planning for major Great Lakes basin-wide research programs.
    b. Develop new research directions.
    c. Develop new projects; coordinate CIGLR's response to new funding opportunities, which includes distributing opportunities among CIGLR PIs, and bringing CIGLR partners into the planning process.
4. Develop and maintain CIGLR's programmatic activities; engage in high-level planning with GLERL on operations, personnel, and partner interactions.
5. Build research and development partnerships between Regional Consortium members and CIGLR and GLERL scientists.
6. Mentor CIGLR's Research Scientists and Postdoctoral Research Fellows.
7. Serve as CIGLR's primary spokesperson to university leadership, NOAA leadership, media outlets, and the public.

8. Provide high-level personnel oversight of research institute staff, including establishing compensation and advancement, discipline, performance issues, etc., in consultation with supervisors.

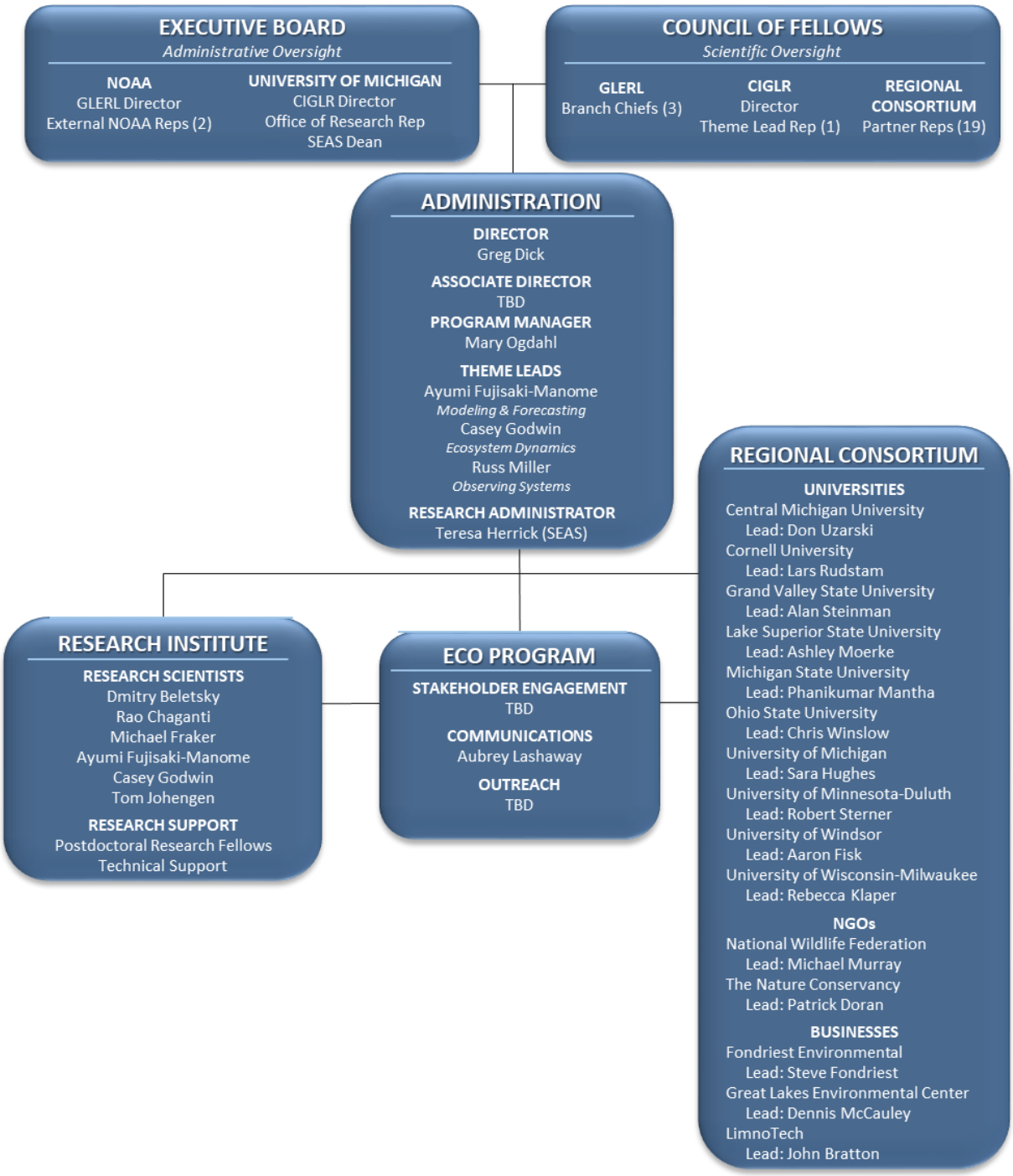

Figure 3. The organizational structure of CIGLR consists of a Research Institute and a Regional Consortium, which are overseen by an administrative leadership team and governed by an Executive Board and Council of Fellows.

Associate Director (to be determined). The Associate Director will co-manage CIGLR's research activities and report to the Director. The Associate Director will complement the Director, leading the following activities in their disciplinary area of expertise (e.g., social science or engineering):

1. Support research coordination and development.
    a. Participate in annual planning for major Great Lakes basin-wide research programs.
    b. Develop new research directions.
2. Develop and maintain CIGLR's programmatic activities.
    a. Engage in high-level planning with GLERL on operations, personnel, and partner interactions.
    b. Build research and development partnerships between Regional Consortium members and CIGLR and GLERL scientists through CIGLR's partner program awards (e.g., postdoctoral fellowships, graduate student fellowships, summits, etc.).
3. Along with Director, co-mentor CIGLR's Research Scientists and Postdoctoral Research Fellows depending on disciplinary focus.
4. On behalf of the Director, serve as CIGLR's primary spokesperson to university leadership, NOAA leadership, media outlets, and the public.

Theme Leads (Russ Miller, Observing Systems; Casey Godwin, Ecosystem Dynamics; Ayumi Fujisaki-Manome, Modeling and Forecasting). The responsibilities of the theme leads are as follows:

1. Communication and coordination of research with GLERL
    a. Maintain regular communication with GLERL Branch Chiefs about ongoing collaborative research, personnel needs, and new funding opportunities.
    b. Represent CIGLR at GLERL meetings (branch meetings, all hands meetings, etc.).
    c. Advocate for CIGLR and its partners in development of research plans within NOAA.
2. Project and personnel management
    a. Oversee the portfolio of funded projects within each theme and perform routine reconnaissance to check that projects are progressing well and meeting NOAA's needs.
    b. Make sure CIGLR staff working in each theme are receiving appropriate training and supervision. Help coordinate annual reviews, and make sure employees are given appropriate goals, and provided opportunities for professional development.
    c. Work with CIGLR's Program Manager to ensure CIGLR personnel have funding each fiscal year, that their time is appropriately distributed among projects, and make adjustments when necessary.
    d. Oversee reporting of funded projects within each theme.
    e. Maintain communication and relations with subcontractors (e.g., MBARI).

3. Communication with CIGLR Administration
    a. Meet monthly with the CIGLR Director, Associate Director, and Program Manager to provide updates on all of the above.
    b. Maintain regular contact with the CIGLR Director, Associate Director, and Program Manager between monthly meetings to communicate problems or time-sensitive needs.
    c. Foster communication and collaboration between CIGLR's Regional Consortium members and PIs at NOAA-GLERL.

Program Manager (Mary Ogdahl). The Program Manager will manage CIGLR's programmatic activities, proposal development, research and administrative budgets, and personnel. The Program Manager's primary responsibilities are as follows:

1. Administration and budget
    a. CIGLR budget. In consultation with the CIGLR Director and Associate Director, help establish funding priorities for CIGLR at the beginning of each fiscal year. Perform quarterly budget projections across ongoing CIGLR projects and administrative accounts and review them with the Research Administrator and Theme Leads. Work with GLERL PIs and administrators during the GLERL annual execution plan (AEP) process to develop CIGLR budget needs for the coming year.
    b. Personnel management. Oversee hiring of all new CIGLR employees. Monitor all personnel assignments on each project, assist PIs with determining staff effort allocations, manage staff effort distribution across projects, and track staff funding (current, pending).
    c. Reporting. Lead preparation and submission of CIGLR's annual research report to NOAA.
2. Research coordination
    a. Promoting consortium partnerships. In coordination with the Director and Associate Director, promote CIGLR's Regional Consortium partnerships by networking to provide collaboration and coordination among researchers, communicating opportunities and updates, and arranging annual meetings.
    b. Fostering research partnerships. Identify funding opportunities & distribute to researchers at GLERL, CIGLR, and Regional Consortium members. Help interested PIs make initial contacts and facilitate proposal development.
    c. Oversee annual project proposal development and submission. Coordinate with the Federal Program Officer to ensure proposal compliance (deadlines, funding availability, NOAA requirements). Work with PIs to prepare budgets and budget justifications and review proposal narratives. Track proposals from planning stage through award notification.
3. ECO Program
    a. Develop, lead, and manage CIGLR's ECO Program activities, including competitive fellowship programs (postdoc, graduate student, Great Lakes Summer Fellows), summits and working groups, and seminar series.
    b. Oversee stakeholder and policy engagement activities.
    c. Oversee outreach activities, including reviewing and approving all

communications products.

d. Build relationships between CIGLR and local media outlets and reporters. Pitch CIGLR news items to media relations (e.g., Michigan News, Michigan Radio, TV news reporters, newspaper journalists).

ECO Program Staff (Aubrey Lashaway & TBD engagement and outreach specialists). ECO Program staff will implement and support CIGLR's ECO Program activities. Responsibilities are to (a) manage and maintain the CIGLR website, (b) lead the preparation of quarterly and annual newsletters, (c) interact with CIGLR Research Institute and Regional Consortium researchers to generate project updates for ECO Program activities and performance tracking, (d) develop and lead CIGLR community outreach activities, (e) develop and lead outreach and engagement activities specifically designed to interact with underrepresented populations, (f) manage CIGLR social media accounts, (g) maintain a database of CIGLR's products and performance tracking metrics, (h) develop and lead CIGLR's stakeholder engagement activities, and (i) provide programmatic support for the Great Lakes Summer Fellows program. ECO Program staff report to the Program Manager.

Research Administrator (Teresa Herrick). The Research Administrator is responsible for the processing grants, contracts, and Cooperative Agreements. The Research Administrator's primary responsibilities are to (a) process all Cooperative Agreement and external grant proposal submissions, (b) perform post-award grant management, (c) establish and monitor sub-awards, and process invoices (d) prepare quarterly budget reports, and (e) ensure compliance with University of Michigan financial policies and procedures. The Research Administrator will report to the SEAS Business Manager.

Research Institute Staff. The responsibilities of CIGLR Research Scientists are to (a) serve as principal investigators on Cooperative Agreement and external proposals, (b) engage in collaborative research with NOAA scientists and Regional Consortium partners, (c) provide research updates to ECO Program staff to facilitate outreach and communications, and (d) mentor undergraduates, graduate students, and postdoctoral fellows. Postdoctoral fellows work with CIGLR and GLERL research scientists to receive early career training in a NOAA mission-related research topic in the Great Lakes. Research support staff work with CIGLR and GLERL principal investigators on technical aspects of their research projects. All research institute staff are expected to produce high-quality research outcomes, such as peer-reviewed publications, technical reports, and presentations at scientific seminars and conferences.

Regional Consortium. The 10 Regional Consortium universities will each designate a co-PI to serve as the primary point of contact for CIGLR administration, research, and ECO Program activities. These co-PIs will be responsible for (a) developing relationships between their university and CIGLR and GLERL scientists, (b) facilitating infrastructure access by NOAA, CIGLR, and Regional Consortium members, (c) communicating with their institution's administration on CIGLR's behalf, (d) providing CIGLR-related research updates to ECO Program staff, (e) ensuring compliance with terms of the CIGLR Memorandum of Understanding (MOU), and (f) serving on the CIGLR Council of Fellows (see below). The 5 Regional Consortium private-sector partners will work with the CIGLR Director to develop and strengthen relationships with CIGLR and GLERL scientists; participate in NOAA research

opportunities; help identify their organization's areas of research, development, applications, and engagement that could enhance NOAA programs; and designate a representative to serve on the CIGLR Council of Fellows.

Fiscal and human resources management

The CI will be administered through the School for Environment and Sustainability (SEAS) at the University of Michigan. Oversight of CIGLR human resources and fiscal management will be the responsibility of SEAS's Director of Budget and Administration (Jeff Keeler). CIGLR will receive financial management and human resources support from the SEAS Business Office, including recruiting, hiring, conflict mediation, promotions, effort management and certification, budget analysis and planning, and financial reporting.

All personnel hired by CIGLR will be employees of the University of Michigan with affiliations in SEAS. All University of Michigan human resource rules and benefits will apply. Consistent with the guidelines for CIs, staff of the new CIGLR will be supervised by an appropriate University of Michigan employee. In cases where CIGLR staff receive technical leadership from NOAA scientists, the University of Michigan supervisor will regularly communicate with the NOAA mentor and the employee to maintain productive working relations. The performance of CIGLR staff will be evaluated annually as part of SEAS's merit review process. For technical staff, performance plans will involve setting 6-month achievement criteria that are used to assess work progress. For research scientists, performance is based on scientific productivity and accomplishments for each annual reporting period.

Strategic planning, accountability, and progress reviews

CIGLR's renewal proposal constitutes the CI strategic plan. Implementation of this plan will be overseen by the Council of Fellows and the Executive Board (see Governance below). The CIGLR Director will hold ultimate responsibility for accountability of the CI and be responsible administratively to the Executive Board and programmatically to the Council of Fellows. The CIGLR Director will report to the Dean of the SEAS at the University of Michigan. CIGLR and GLERL will also form a Management Team that will meet monthly to discuss the CI's programmatic and operational progress. The Management Team will consist of the GLERL Director/Technical Program Manager, Deputy Director, and Federal Program Officer, and the CIGLR Director, Associate Director, and Program Manager. Science planning and coordination will occur primarily through CIGLR's three Theme Leads, who provide scientific leadership for CIGLR in communication and coordination of ongoing collaborative research, personnel needs, and new funding opportunities with their corresponding NOAA GLERL Branch Chiefs (Fig. 2). In this capacity, Theme Leads will represent and advocate for the interests of CIGLR research scientists, staff, and Regional Consortium partners in cooperative science planning during NOAA GLERL's Annual Execution Plan process and Science Council meetings. Ongoing project planning will take place at NOAA GLERL monthly branch team meetings, where CIGLR Theme Leads, research scientists, and research support staff join their NOAA GLERL colleagues to share research updates, plan for upcoming project needs, and discuss research outcomes. Additional planning and coordination with the Regional Consortium will occur during the annual All Partners meeting, which convenes members of the CIGLR Research Institute, Regional Consortium, and NOAA GLERL to coordinate research goals and activities and foster new research interactions. Basin-wide planning and coordination will also take place through our membership in the NOAA Great Lakes Regional Collaboration Team (GLRCT).

CIGLR will present an annual report of performance measures to the Executive Board, who will provide recommendations for improvement. This annual progress report will track progress toward strategic plan goals. The annual progress reports and Executive Board reviews will be used to prepare for the 5-year CI Science Advisory Board review. Performance measures to be included in the report are in Section VII.

Governance

The CI will be governed by two advisory boards, consistent with NOAA's CI Handbook[30]. CIGLR will receive "One NOAA" oversight and direction from the Executive Board and scientific oversight from the Council of Fellows (Fig. 3).

Executive Board. The Executive Board will provide oversight related to NOAA policies, priorities, and coordination and consist of (a) 2 NOAA representatives from Line Offices outside of the Office of Ocean and Atmospheric Research (OAR) (b) the Director of the Great Lakes Environmental Research Lab (GLERL); (c) the University of Michigan Vice President for Research (or designee), (d) the CI Director (ex officio), and (e) the Dean of SEAS. The Executive Board will meet once per year, and be responsible for:

- Reviewing and providing recommendations on CIGLR's progress toward strategic plan implementation.
- Reviewing and commenting on the annual progress report of the CI.
- Communicating NOAA policies and priorities as they relate to CI operations and science development.
- Assuring that CIGLR maintains a collaborative approach in the Great Lakes and fully engages NOAA and the Regional Consortium in research, outreach, education, and communications.
- Identifying and coordinating opportunities for CI to collaborate with NOAA and their partners.

Council of Fellows. The Council of Fellows will provide scientific oversight and consist of (a) the Branch Chiefs of GLERL's 3 research areas, (b) the CIGLR Director, (c) the CIGLR Associate Director, (d) 1 appointed CIGLR Research Scientist, (e) co-PIs from each of the 10 Regional Consortium universities, and (f) representatives from each of the 5 Regional Consortium private-sector partners. The Council of Fellows will meet two times per year, and be responsible for:

- Providing leadership in maintaining high standards of research for the CI.
- Analyzing the CI's programs and science direction, identifying critical research needs, and recommending new research foci.
- Advising CIGLR's Director on selection of new Council of Fellows members and reappointment of current Fellows.
- Making recommendations to the CIGLR Director on the selection of Visiting Fellows.
- Reviewing grants and applications from Task IB non-administrative programs, including the Postdoctoral Fellowships, Visiting Fellows, and Graduate Research Fellowships, and making recommendations to the CIGLR Director about priority applicants.

Project identification and selection

On an annual basis, the CIGLR Council of Fellows will meet to identify critical research needs in the Great Lakes basin, and potential research teams to address these needs if funding becomes available. CIGLR funding opportunities include (a) direct solicitation from our NOAA host lab (NOAA-GLERL), other Line Offices, or NOAA programs in response to an immediate research need (Task II research), (b) Federal funding opportunities (FFOs) associated with open NOAA award competition (Tasks II and III), and (c) external award competitions related to NOAA's mission, typically in collaboration with NOAA scientists. The Council of Fellows will develop criteria to guide CIGLR responses to funding opportunities, including identifying the most appropriate research team and selecting the best project to propose. When funding opportunities arise, the CIGLR Director and Associate Director will communicate with the Council of Fellows to begin the team identification, project selection, and proposal development process.

Communication and collaboration with NOAA

CIGLR's long history of collocation and integration with NOAA-GLERL has formed a foundation of strong communication and collaboration with NOAA. At the administrative level, CIGLR and NOAA-GLERL will continue to interact and collaborate through the joint Management Team (described above). In cases when CIGLR staff are working with a NOAA scientist, CIGLR supervisors will hold quarterly meetings with the staff person and NOAA mentor, to assure that high standards of performance are being met. CIGLR Research Scientists and research support staff will continue to attend monthly NOAA-GLERL research branch team meetings, where they share research updates, plan for upcoming project needs, and discuss research outcomes. All CIGLR employees will attend NOAA-GLERL All Hands meetings and receive building-wide email updates to stay informed of policies, procedures, and opportunities. CIGLR will continue to participate in NOAA communications and outreach efforts at multiple levels, including monthly Information Services (IS) Communications Group meetings, where we coordinate and strategize CI and NOAA-GLERL activities, share successes and ideas for improvement, and receive guidance on working with the larger NOAA communications network. We participate in monthly meetings of the NOAA Great Lakes Regional Collaboration Team (GLRCT) Communications and Outreach Working Group, composed of representatives from CIGLR, NOAA Line Offices, Great Lakes Sea Grant Network, and the Great Lakes Observing System (GLOS). CIGLR also maintains communication with the NOAA CI Administrative Office (CIAO) and participates in CI Director and Administrator group meetings.

VII. Performance measures

To assess progress annually, CIGLR will track performance measures within 7 categories that capture our productivity and impacts. Annual summaries of performance measures will be produced for review and comment by the CIGLR Executive Board, and for the annual Performance Progress Report to the CI Program Office. Select performance measures will be updated on the CIGLR website and included in quarterly newsletters. CIGLR's performance and impacts will be assessed by the following measures:

Grant Success

- Total NOAA grant funding and number of amendments awarded to CIGLR through CA. Target: \$6 million yr^{-1}, 25 amendments.
- External funds awarded to CIGLR PIs, including competitive NOAA funds linked to the CA and non-NOAA funds. Target: \$750K yr^{-1}.
- Number of CIGLR Research Institute personnel supported through CA and external funding. Target: 38.

NOAA-University Partnership

- CIGLR Research Institute contribution to GLERL scientific workforce, as percentage of research personnel. Target: 60%.
- CIGLR contribution to GLERL's scientific productivity, as percentage of publications and technical reports co-authored by Research Institute or Regional Consortium members. Target: 60%.
- University of Michigan cost share and in-kind support. Target: ≥\$711K yr^{-1} average.
- Regional Consortium cost share funding and in-kind support. Target: ≥\$480K yr^{-1}.
- Number of NOAA, CIGLR Research Institute, and Regional Consortium scientists performing visiting research at a NOAA-GLERL or Regional Consortium facility. Target: 3 yr^{-1}.
- Number of times Regional Consortium facilities are accessed by NOAA, CIGLR Research Institute, or other Regional Consortium researchers. Target: 5 yr^{-1}.

Regional Collaboration

- Number and amount of sub-award funding issued to Regional Consortium members. Target: \$2.1 million yr^{-1} and 15 sub-awards yr^{-1}, with >65% to Regional Consortium members.
- Percentage of total CIGLR research (Tasks II and III) and programmatic funding sub-awarded to Regional Consortium members. Target: ≥30%.
- Number of Regional Consortium PIs receiving sub-awards. Target: ≥50 unique PIs over the 5-year CA.
- Number of institutions, organizations, and businesses receiving sub-awards. Target: ≥20 unique recipients over the 5-year CA.
- Number of Regional Consortium-affiliated students receiving support. Target: 40 yr^{-1}.
- Number of Summits and Working Groups funded; number and type of products from Summits and Working Groups. Target: 3 summits or working groups yr^{-1}; 1 peer-reviewed publication or summary white paper from each.

Research Outcomes

- Number of peer-reviewed publications resulting from CIGLR funding; number of peer-reviewed publications with CIGLR-funded first authors. Target: 40 publications yr^{-1}; 15 first-authored publications yr^{-1}.
- Number of citations for all CIGLR-produced peer-reviewed publications. Target: 200 citations per year; 1,000 citations during the 5-year CA.
- Altmetric scores for CIGLR publications. Target: 1 articles yr^{-1} with scores ≥ 100.
- Number of social & news media hits related to CIGLR publications. Target: 200 yr^{-1}.

Policy Impact

- Number of public decisions (laws, policies, funding initiatives) affected by CIGLR science and advocacy. Target: 2 during the 5-year CA.
- Number of legislative actions, policy documents, and congressional/legislative hearings referencing CIGLR research. Target: 2 during the 5-year CA.
- Number of inquiries about CIGLR research by elected officials, agencies, and regulatory bodies. Target: 5 during the 5-year CA.
- Number white papers and/or published journal articles that address Great Lakes research/funding priorities. Target: 1 during the 5-year CA.

Career Training

- Number of undergraduates, graduate students, and postdocs receiving support through CIGLR. Target: 60 yr^{-1}.
- Amount of funding to support student and postdoctoral fellowships, student employees, and postdoctoral employees. Target: $1.5 million yr^{-1}.
- Number of students and postdocs located at GLERL. Target: 20 yr^{-1}.
- Number of student and postdoctoral fellowships awarded. Target: 12 yr^{-1}.
- Number of university affiliations of supported students. Target: 15 yr^{-1}.
- Number of CI students, postdocs, and staff obtaining NOAA employment. Target: 1 yr^{-1}.
- Number of CIGLR and GLERL peer-reviewed publications and technical reports co-authored by students. Target: 8 yr^{-1}.
- Percentage of self-identified non-white/Caucasian and female fellowship applicants. Target: >25% non-white/Caucasian and >50% non-male.

Outreach and Communications

- Number of in-person and virtual (webinar) Seminar Series attendees; number of seminar recording views on YouTube. Target: 50 total attendees per seminar, 50 online views.
- Website metrics, including number of hits and popular pages. Target: 20,000 visits $month^{-1}$, 2,000 visitors $month^{-1}$ (site-wide).
- Number of social media followers; social media engagement/reach metrics. Target: 2,000 followers on Facebook and Instagram, >4,000 followers on Twitter.
- Number of press releases picked up by media; number of interview requests; number of stories and videos produced by Michigan News. Target: 5 press releases yr^{-1}, 15 interview requests yr^{-1}, 4 Michigan News stories yr^{-1}.
- Number of NOAA OAR Hot Item articles submitted. Target: 20 Hot Items yr^{-1} submitted.
- Number of e-newsletter subscribers; percentage of e-newsletter opens/views. Target:

>800 subscribers, >35% open rate.

- Number of annual news magazine subscribers; percentage of electronic opens/views. Target: >2500 subscribers.

VIII. Attachments to Project Narrative

A. Budget narrative

Cooperative Institute for Great Lakes Research (CIGLR), July 1, 2022 - June 30, 2027 *Page 1*
Oceanic & Atmospheric Research (OAR), National Oceanic & Atmospheric Administration (NOAA), US Department of Commerce
The Cooperative Institute for Great Lakes Research Renewal

		7/1/22-6/30/23	7/1/23-6/30/24	7/1/24-6/30/25	7/1/25-6/30/26	7/1/26-6/30/27	Total
Task IA - Administration							
Personnel	FTE						
Director	0.25	59,925	61,124	62,346	63,593	64,865	311,853
Associate Director	0.10	13,500	13,770	14,045	14,326	14,613	70,254
Theme Leads (3)	0.15	11,707	11,941	12,180	12,424	12,673	60,925
Program Manager	1.00	91,375	93,203	95,067	96,968	98,907	475,520
Communications Specialist	1.00	63,240	64,505	65,795	67,111	68,453	329,104
Outreach Specialist	0.50	23,000	23,460	23,929	24,408	24,896	119,693
Engagement Specialist	0.50	35,000	35,700	36,414	37,142	37,885	182,141
Research Administrator	0.40	36,318	37,044	37,785	38,541	39,312	189,000
Fringe benefits							
Director	30%	17,978	18,337	18,704	19,078	19,460	93,557
Associate Director	30%	4,050	4,131	4,214	4,298	4,384	21,077
Theme Leads (3)	30%	3,512	3,582	3,654	3,727	3,802	18,277
Program Manager	30%	27,413	27,961	28,520	29,090	29,672	142,656
Communications Specialist	30%	18,972	19,352	19,739	20,133	20,536	98,732
Outreach Specialist	30%	6,900	7,038	7,179	7,322	7,469	35,908
Engagement Specialist	30%	10,500	10,710	10,924	11,143	11,366	54,643
Research Administrator	30%	10,895	11,113	11,336	11,562	11,794	56,700
Travel		6,000	6,000	6,000	6,000	6,000	30,000
Office supplies/communications		1,800	1,800	1,800	1,800	1,800	9,000
Sub-Total Task IA Direct Cost		442,085	450,772	459,631	468,667	477,887	2,299,042
Indirect Cost Task IA	0%	-	-	-	-	-	-
Sub-Total Task IA		442,085	450,772	459,631	468,667	477,887	2,299,042
Task IB - Education & Outreach							
Hosting (seminar series)		500	500	500	500	500	2,500
Travel (seminar series)		1,200	1,200	1,200	1,200	1,200	6,000
Webinar subscription (seminar series)		800	800	800	800	800	4,000
Summer student fellowships		60,000	60,000	60,000	60,000	60,000	300,000
Graduate fellowships (Regional Consortium Sub-awards)		80,000	80,000	80,000	80,000	80,000	400,000
Sub-Total Task IB Direct Cost		142,500	142,500	142,500	142,500	142,500	712,500
Indirect Cost Task IB	26%	650	650	650	650	650	3,250
Sub-Total Task IB		143,150	143,150	143,150	143,150	143,150	715,750

		7/1/22-6/30/23	7/1/23-6/30/24	7/1/24-6/30/25	7/1/25-6/30/26	7/1/26-6/30/27	Total
Tasks II & III - Research							
Personnel	FTE						
Research Scientists	0.6	88,947	90,726	92,541	94,392	96,280	462,886
Assistant Research Scientists	7.6	603,637	615,710	628,024	640,584	653,396	3,141,351
Research Support Staff @ GLERL	32	1,940,724	1,979,538	2,019,129	2,059,512	2,100,702	10,099,605
Postdoctoral Fellows	12	644,640	657,533	670,684	684,098	697,780	3,354,735
Grad. Student Research Assistants	8	243,936	248,815	253,791	258,867	264,044	1,269,453
Hourly Student Assistants	10	156,300	159,426	162,615	165,867	169,184	813,392
Fringe benefits							
Research Scientists	30%	26,684	27,218	27,762	28,318	28,884	138,866
Assistant Research Scientists	30%	181,091	184,713	188,407	192,175	196,019	942,405
Research Support Staff @ GLERL	30%	582,217	593,861	605,739	617,854	630,211	3,029,882
Postdoctoral Fellows	30%	193,392	197,260	201,205	205,229	209,334	1,006,420
Grad. Student Research Assistants	26%	63,423	64,692	65,986	67,305	68,651	330,057
Hourly Student Assistants (8%)	8%	12,504	12,754	13,009	13,269	13,535	65,071
Travel		130,000	130,000	130,000	130,000	130,000	650,000
Equipment		250,000	156,000	120,000	60,000	-	586,000
Research supplies & services		200,000	200,000	150,000	115,000	60,000	725,000
Student fellowships	12	120,000	120,000	120,000	120,000	120,000	600,000
Tuition	8	192,000	195,840	199,757	203,752	207,827	999,176
Subawards to Regional Consortium		3,067,721	3,029,808	2,994,258	2,961,119	2,950,431	15,003,337
Sub-Total Task II & III Direct Cost		8,697,216	8,663,894	8,642,907	8,617,341	8,596,278	43,217,636
Sub-Total Task II & III Mod. Direct Cost		5,067,495	5,162,246	5,208,892	5,272,470	5,318,020	26,029,123
Indirect Cost Task II & III	26%	1,317,549	1,342,184	1,354,312	1,370,842	1,382,685	6,767,572
Sub-Total Task II & III		10,014,765	10,006,078	9,997,219	9,988,183	9,978,963	49,985,208
TOTAL Tasks I-III		10,600,000	10,600,000	10,600,000	10,600,000	10,600,000	**53,000,000**
Cost Share							
Personnel							
Director	0.25	59,925	61,124	62,346	63,593	64,865	311,853
Engagement Specialist	0.5	35,000	35,700	36,414	37,142	37,885	182,141
Research Scientists (7)	0.35	30,341	30,948	31,567	32,198	32,842	157,896
SEAS Finance	0.50	55,863	56,980	58,120	59,282	60,468	290,713
SEAS Human Resources	0.15	10,421	10,629	10,842	11,059	11,280	54,231
SEAS Procurement	0.15	8,192	8,356	8,523	8,693	8,867	42,631
Fringe benefits							
Director	30%	17,978	18,337	18,704	19,078	19,460	93,557
Engagement Specialist	30%	10,500	10,710	10,924	11,143	11,366	54,643
Research Scientists (7)	30%	9,102	9,284	9,470	9,659	9,853	47,368
SEAS Finance	30%	16,759	17,094	17,436	17,785	18,140	87,214
SEAS Human Resources	30%	3,126	3,189	3,253	3,318	3,384	16,270
SEAS Procurement	30%	2,458	2,507	2,557	2,608	2,660	12,790
Partner programs (Regional Consortium Sub-awards)							
Fellowships (graduate students and postdocs)		310,000	310,000	310,000	310,000	310,000	1,550,000
Seed funds		36,000	36,000	36,000	36,000	36,000	180,000
Summits & working groups		60,000	60,000	60,000	60,000	60,000	300,000
ECO funds		16,000	16,000	16,000	16,000	16,000	80,000
Program support (annual magazine, student events, outreach materials)		20,500	19,590	18,662	17,715	16,749	93,216
Total Cost Share expenses		702,165	706,448	710,818	715,273	719,819	3,554,523
Total Cost Share contribution - University of Michigan		702,165	706,448	710,818	715,273	719,819	3,554,523

Budget Justification

The requested budget partially supports the administrative, programmatic, and research activities described in this proposal. Additional support for the proposed activities will come from the University of Michigan Cost Share and in-kind support from both the University of Michigan and the Regional Consortium. Budget requests are described below by task, including Task IA administrative costs, Task IB education and outreach programmatic costs, and combined Tasks II and III research costs. While these budgets provide cost estimates for supporting CIGLR activities, we acknowledge that actual Task IB, II, and III budgets will be based on submission and NOAA approval of separate annual project proposals, awarded as amendments to the parent Cooperative Agreement. Accordingly, we also acknowledge that the annual Task IA budget will be determined as a percentage of Task II and III funding, established annually by the CI Administrative Office.

Task I. Task I activities are related to the overall management of the CI and to overall education and outreach activities not linked to specific research projects. Task I activities are divided into two categories: Task IA – Administration and Task IB – Education and Outreach.

Task IA - Administration $2,299,042

Task IA funds in the amount of $2,299,042 are requested to support salary and fringe benefits for CIGLR administrative staff and CIGLR operational costs.

A. Salary $1,738,490

Funds ($311,853) are requested to provide the Director with 0.25 FTE support per year to oversee the administration and budget of CIGLR, develop and maintain CIGLR's programmatic activities, build research and development, mentor CIGLR's Research Scientists and postdocs, and serve as CIGLR's primary spokesperson. Funds ($70,254) are requested to provide the Associate Director with 0.1 FTE support per year to support research coordination and development, develop and maintain CIGLR's programmatic activities, co-mentor CIGLR's Research Scientists and postdocs, and serve as spokesperson for CIGLR on the Director's behalf. Funds ($60,925) are requested to provide each of the 3 Theme Leads with 0.05 FTE support per year for communication and coordination of research with NOAA-GLERL, project and personnel management, and foster collaboration between the Regional Consortium and NOAA-GLERL. Funds ($475,520) are requested to provide the Program Manager with 1 FTE support per year for leading the development and implementation of the Engagement, Career Training, and Outreach (ECO) Program, creating and maintaining budget projections, managing CIGLR personnel, overseeing research proposal development, and leading the preparation of CIGLR's annual Research Performance Progress Report. Funds ($329,104) are requested to provide the Communications Specialist with 1 FTE support per year to manage and maintain the CIGLR website, lead the preparation of quarterly and annual newsletters, manage CIGLR social media accounts, and maintain a database of CIGLR's products and performance tracking metrics. Funds ($119,693) are requested to provide the Outreach Specialist with 0.5 FTE support per year to develop and lead CIGLR community outreach activities. Funds ($182,141) are requested to provide the Engagement Specialist with 0.5 FTE support per year to develop and lead CIGLR's stakeholder engagement activities. Funds ($189,000) are requested to provide 0.4 FTE support per year to the SEAS Research Administrator to process all Cooperative Agreement and external grant proposal submissions, perform post-award grant management, establish and monitor sub-awards, process invoices, prepare quarterly budget reports, and ensure compliance with University of Michigan financial policies and procedures.

B. Fringe Benefits $521,550

Fringe benefit rates for permanent University of Michigan employees are based on actual costs and vary depending on the coverage selected by the employee. An average fringe benefit percentage of 30% was applied for Task IA administrative staff.

C. Travel – Domestic $30,000

Travel support is requested for (1) the Director and Program Manager to travel to NOAA Headquarters in Silver Spring, Maryland for the annual CI Directors' Meeting, (2) the Program Manager to attend the annual CI Administrators' Meeting (various locations), and (3) collaborative research planning meetings between the Director and Regional Consortium members.

1. CI Directors' Meeting (Silver Spring, MD)
   Estimated cost: $3,600/year x 5 years = $18,000
2. CI Administrators' Meeting (Various CI locations)
   Estimated cost: $1,200/year x 5 years = $6,000
3. Collaborative research planning meetings (Various)
   Estimated cost = $1,200/year x 5 years = $6,000

D. Supplies & Communications $9,000

Funds are requested to purchase general office supplies such as printer paper, notebooks, envelopes, writing utensils, etc., for the CIGLR administrative office at the University of Michigan. Estimated office supply costs are $1,000 per year. Funds are also requested for annual webinar service subscription, estimated at $800 per year.

E. Task IA Total Direct Cost $2,299,042

F. Task IA Indirect Cost $0

The University of Michigan will waive indirect costs on Task IA funds.

G. Task IA Total Cost $2,299,042

Task IB – Education and Outreach $715,750

Task IB funds in the amount of $715,750 are requested to support a portion of CIGLR's Engagement, Career Training, and Outreach (ECO) Program activities. Specific programs to be supported are the Summer Fellowship program, Great Lakes Seminar Series, and the Graduate Research Fellowship program. Other ECO Program activities are supported by the University of Michigan Cost Share (see below).

A. Summer Student Fellowship Program $300,000

Funds are requested to support the Great Lakes Summer Fellows program. CIGLR will provide summer fellowships to 6 undergraduates and graduate students per year. Each student fellow will receive a $10,000 stipend.

6 fellowships per year x $10,000 stipend x 5 years = $300,000

B. Seminar Series $12,500

Funds are requested to partially support the Great Lakes Seminar Series, which comprises 12 total

invited seminars per year. The requested funds will be used for hosting expenses for 6 seminars, travel expenses for 2 speakers, and partial support for an annual webinar service subscription. Hosting expenses will include refreshments (coffee, tea, soft drinks, snacks) for an audience of approximately 60 seminar guests for each event. Guests will include CIGLR faculty and staff, NOAA-GLERL employees, local partners, and the public. The seminar series is part of CIGLR's Engagement, Career Training, and Outreach (ECO) Program, which is designed to fulfill NOAA requirements for educational programming. This program is cost-shared with the University of Michigan (see Cost Share section).

Hosting: 6 seminars per year x $83 per seminar x 5 years = $2,500
Travel: 2 speakers per year x $1,200 per speaker x 5 years = $6,000
Webinar service: $800 per year x 5 years = $4,000

C. Graduate Research Fellowships (Sub-awards) $400,000

Funds are requested to support 2 Great Lakes Graduate Research Fellowships per year. Graduate Research Fellowships will be $40,000 each and competitively sub-awarded to Regional Consortium principal investigators to support graduate students at their institutions. Although these are competitively awarded based on an annual request for proposals, we will make an effort to evenly distribute programmatic funds among members. We anticipate that student and postdoc opportunities (i.e., fellowships, ECO funds) will be awarded to Regional Consortium universities, with involvement from private-sector partners.

	7/1/22-6/30/23	7/1/23-6/30/24	7/1/24-6/30/25	7/1/25-6/30/26	7/1/26-6/30/27	Total
Task IB Sub-awards to Regional Consortium Members						
Central Michigan University	40,000	-	-	-	-	40,000
Cornell University	40,000	-	-	-	-	40,000
Grand Valley State University	-	40,000	-	-	-	40,000
Lake Superior State University	-	40,000	-	-	-	40,000
Michigan State University	-	-	40,000	-	-	40,000
Ohio State University	-	-	40,000	-	-	40,000
University of Michigan	-	-	-	40,000	-	40,000
University of Minnesota Duluth	-	-	-	40,000	-	40,000
University of Windsor	-	-	-	-	40,000	40,000
University of Wisconsin Milwaukee	-	-	-	-	40,000	40,000
Total Task IB Sub-awards	80,000	80,000	80,000	80,000	80,000	**400,000**

D. Task IB Direct Cost $712,500

E. Task IB Modified Total Direct Cost $12,500

The University of Michigan will not charge indirect costs on fellowships or sub-awards to Regional Consortium members.

F. Task IB Indirect Cost $3,250

An indirect cost rate of 26% will be charged on Task IB Modified Total Direct Costs. This rate is equivalent to the University of Michigan off-campus rate and the rate established between the University of Michigan and NOAA for activities funded within the CIGLR Cooperative Agreement.

Tasks II & III. Tasks II and III budgets include costs related to CI research activities,

including salary, fringe benefits, travel, equipment, supplies, and research sub-awards to Regional Consortium members. Task II research involves ongoing collaboration with NOAA scientists, typically fostered by the collocation of CI and NOAA employees. Task III research activities are related to the NOAA and CI mission, but do not involve direct collaboration with NOAA scientists. Task III activities may include research funded by other NOAA competitive grant programs. Although we anticipate that CIGLR research will primarily be Task II activity, we cannot predict the division of Task II and III research and thus present these budgets together.

G. Salary $19,141,422

Funds are requested for salary support of CIGLR Research Institute faculty, staff, postdocs, and students employed by the University of Michigan and collocated with NOAA-GLERL. Research Scientists and Assistant Research Scientists (0.6 FTE per year, $462,886 total; and 7.6 FTE per year, $3,141,351 total, respectively) will serve as principal investigators on Cooperative Agreement and external proposals, engage in collaborative research with NOAA scientists and Regional Consortium partners, and mentor undergraduates, graduate students, and postdoctoral fellows. Research support staff (32 FTE per year; $10,099,605 total) will work with CIGLR and GLERL principal investigators on technical aspects of their research projects. Postdoctoral fellows (12 FTE per year; $3,354,735 total) will work with CIGLR and GLERL Research Scientists to receive early career training in a NOAA mission-related research topic in the Great Lakes. All Research Institute faculty, staff, and postdocs will produce high-quality research outcomes, such as peer-reviewed publications, technical reports, and presentations at scientific seminars and conferences. Graduate Student Research Assistants (8 per year; $1,269,453 total) will work with a CIGLR or GLERL principal investigator to complete a graduate research assistantship, which may include thesis or dissertation research. Hourly Student Assistants (10 students; $813,392 total) will provide CIGLR and GLERL principal investigators with technical research support.

H. Fringe Benefits $5,512,701

Fringe benefit rates for permanent University of Michigan employees are based on actual costs and vary depending on the coverage selected by the employee. An average fringe benefit percentage of 30% was applied to all permanent Task II research staff. Fringe benefits for Graduate Student Research Assistants are 26%. Fringe benefit rates for hourly University of Michigan employees are calculated at a rate of 8% of salary to cover FICA costs.

I. Travel – Domestic $650,000

Funds are requested to support research project-related travel, including field work, scientific conferences, workshops, trainings, and meetings. Travel funds will be used by CIGLR Research Scientists, staff, and students. The estimated travel cost per year is $130,000. Specific travel plans will be identified and proposed during the annual research planning process. The estimates and distribution of travel costs were based on historical travel expenses and expected growth over the next 5 years.

J. Equipment $586,000

Funds are requested to purchase lab and field equipment needed to execute CIGLR research projects. Specific pieces of equipment to be purchased will be identified and proposed during the annual research planning process. The estimates and distribution of equipment costs were based on historical equipment expenses and expected growth over the next 5 years.

K. Research Supplies and Services $725,000

Funds are requested to purchase field and laboratory supplies needed to execute CIGLR research projects. These funds will also be used for communications services related to operating CIGLR observing systems. Specific research supplies and services to be purchased will be identified and proposed during the annual research planning process. The estimates and distribution of supply and services costs were based on the historical expenses expected growth over the next 5 years.

L. Fellowships $600,000

Funds are requested to support student fellowships (12 per year; $120,000) to work with CIGLR and GLERL principal investigators on components of CIGLR research projects.

M. Tuition $999,176

Funds are requested to support full-time tuition waivers for Graduate Student Research Assistants (8 per year) as part of their research assistant package to work with CIGLR and GLERL principal investigators.

N. Regional Consortium Research (Sub-awards) $15,003,337

Funds are requested to support cooperative research by members of the CIGLR Regional Consortium. CIGLR will issue Task II and III sub-awards to Regional Consortium principal investigators equivalent to approximately 30% of the total Task II and III research funds. Estimates are provided below for expected amounts to each Regional Consortium member, based on historical research activity and anticipated future projects. Actual sub-award amounts will be determined based on annual Task II/III project needs, as identified by CIGLR and NOAA-GLERL. Additional sub-awards will be issued to Regional Consortium members using Cost Share funds (described below), through which we anticipate the majority of our funded interactions with private-sector partners will occur. The University of Michigan will waive indirect charges on Task II/III sub-awards to Regional Consortium members and charge 26% on the first $25,000 of sub-awards to other institutions. Indirect costs for sub-awards to University of Michigan principal investigators outside of the Research Institute will be charged at the off-campus rate of 26%.

	7/1/22-6/30/23	7/1/23-6/30/24	7/1/24-6/30/25	7/1/25-6/30/26	7/1/26-6/30/27	Total
Task II Sub-awards to Regional Consortium Members						
Central Michigan University	306,773	302,980	299,424	296,111	295,043	1,500,331
Cornell University	153,386	151,490	149,713	148,056	147,522	750,167
Grand Valley State University	306,772	302,981	299,426	296,112	295,043	1,500,334
Lake Superior State University	306,772	302,981	299,426	296,112	295,043	1,500,334
Michigan State University	306,772	302,981	299,426	296,112	295,043	1,500,334
Ohio State University	306,772	302,981	299,426	296,112	295,043	1,500,334
University of Michigan	613,544	605,962	598,852	592,224	590,086	3,000,668
University of Minnesota Duluth	276,095	272,683	269,483	266,501	265,539	1,350,301
University of Windsor	153,386	151,490	149,713	148,056	147,522	750,167
University of Wisconsin Milwaukee	306,772	302,981	299,426	296,112	295,043	1,500,334
The Nature Conservancy	-	-	-	-	-	-
National Wildlife Federation	-	-	-	-	-	-

LimnoTech	30,677	30,298	29,943	29,611	29,504	150,033
Fondreist Environmental	-	-	-	-	-	-
Great Lakes Environmental Center	-	-	-	-	-	-
Total Task II Sub-awards	3,067,721	3,029,808	2,994,258	2,961,119	2,950,431	**15,003,337**

O. Task II and III Direct Cost $43,217,636

P. Task II and III Modified Total Direct Cost $26,029,123

The University of Michigan will not charge indirect costs on equipment, fellowships, tuition, sub-awards to Regional Consortium members, or other sub-awards over $25,000.

Q. Task II and III Indirect Cost $6,767,572

An indirect cost rate of 26% will be charged on Task II Modified Total Direct Costs. This rate is equivalent to the University of Michigan off-campus rate and the rate established between the University of Michigan and NOAA for CIGLR research.

R. Task II and III Total Cost $49,985,208

S. Total Tasks I-III Cost $53,000,000

Task IA= $2,299,042
Task IB = $715,750
Task II/III= $49,985,208
Total = $53,000,000

Cost Share by Host $3,554,523

The University of Michigan has committed to partner with NOAA by cost sharing CIGLR Task IB programs and administrative support in the amount of $3,554,523. Annual cost share contributions will come from the University of Michigan's Office of the Vice President for Research, the School for Environment and Sustainability (SEAS), the School of Engineering, the School of Literature, Sciences, and the Arts (LSA), and the School of Public Health.

	7/1/22-6/30/23	7/1/23-6/30/24	7/1/24-6/30/25	7/1/25-6/30/26	7/1/26-6/30/27	Total
Cost Share - University of Michigan						
Office of the Vice President for Research	300,000	300,000	300,000	300,000	300,000	1,500,000
School for Environment & Sustainability	344,165	348,448	352,818	357,273	361,819	1,764,523
College of Engineering	25,000	25,000	25,000	25,000	25,000	125,000
School of Literature, Science, & Arts	32,000	32,000	32,000	32,000	32,000	160,000
School of Public Health	1,000	1,000	1,000	1,000	1,000	5,000
Total Cost Share	702,165	706,448	710,818	715,273	719,819	**3,554,523**

A. Personnel $1,039,465

Cost share funds will be used to partially support the CIGLR Director (0.25 FTE per year; $311,853 total), Engagement Specialist (0.5 FTE per year; $182,141 total), and 7 Research Scientists (0.05 FTE per year each; $157,896 total). Cost share funds will also support 0.8 FTE per year ($387,575 total) for SEAS finance, human resources, and procurement staff performing CIGLR functions.

B. Fringe Benefits $311,842

Fringe benefit rates for permanent University of Michigan employees are based on actual costs and vary depending on the coverage selected by the employee. An average fringe benefit percentage of 30% was applied to the Director, Engagement Specialist, Research Scientists, and SEAS administrative support staff.

C. Partner Programs (Regional Consortium Sub-awards) $2,110,000

Cost share funds will be used to support CIGLR partner programs that connect CIGLR and NOAA-GLERL researchers with Regional Consortium members. These programs include Postdoctoral Fellowships (3 per year; $1,350,000 total), Graduate Fellowships (1 per year; $200,000 total), Summits and Working Groups (3 per year; $300,000 total), Seed Funds (3 per year; $180,000 total), and ECO Funds (2 per year; $80,000 total). Although these are competitively awarded based on an annual request for proposals, we will make an effort to evenly distribute programmatic funds among members. We anticipate that student and postdoc opportunities (i.e., fellowships, ECO funds) will be awarded to Regional Consortium universities, with involvement from private-sector partners. Summits and working groups and seed funds may be awarded to any Regional Consortium member.

	7/1/22-6/30/23	7/1/23-6/30/24	7/1/24-6/30/25	7/1/25-6/30/26	7/1/26-6/30/27	Total
Cost Share Sub-awards to Regional Consortium Members						
Central Michigan University	90,000	8,000	8,000	90,000	-	196,000
Cornell University	90,000	20,000	-	90,000	-	200,000
Grand Valley State University	90,000	20,000	8,000	40,000	40,000	198,000
Lake Superior State University	48,000	90,000	12,000	20,000	20,000	190,000
Michigan State University	32,000	90,000	32,000	12,000	28,000	194,000
Ohio State University	12,000	90,000	-	8,000	90,000	200,000
University of Michigan	20,000	40,000	90,000	20,000	20,000	190,000
University of Minnesota Duluth	-	12,000	90,000	-	90,000	192,000
University of Windsor	-	12,000	90,000	-	90,000	192,000
University of Wisconsin Milwaukee	20,000	8,000	60,000	90,000	20,000	198,000
The Nature Conservancy	20,000	12,000	-	-	-	32,000
National Wildlife Federation	-	20,000	12,000	-	-	32,000
LimnoTech	-	-	20,000	12,000	-	32,000
Fondreist Environmental	-	-	-	20,000	12,000	32,000
Great Lakes Environmental Center	-	-	-	20,000	12,000	32,000
Total Cost Share Sub-awards	422,000	422,000	422,000	422,000	422,000	**2,110,000**

D. Program Support $93,216

Cost share funds will also be used to support programmatic expenses, including annual magazine publication, web services, student events, conference sponsorship, outreach materials, and the Great Lakes Seminar Series (hosting and guest travel).

In-Kind Support

The University of Michigan and Regional Consortium members have committed to contribute to the NOAA partnership through in-kind support as described below.

Host

As host of the CI, the University of Michigan will provide CIGLR with in-kind support, including dedicated office and laboratory space in SEAS, administrative release time for CIGLR Research Scientists, IDC waivers on all sub-awards to Regional Consortium members, and an IDC waiver on Task IA funds. All Task II funding to University of Michigan principal investigators outside of CIGLR is subject to a reduced IDC rate.

Regional Consortium

In their Memoranda of Understanding with the University of Michigan (Appendix 4), Regional Consortium members agreed to reduced indirect cost rates for NOAA research sub-awards through CIGLR, reduced indirect costs on partner program awards, and full access by NOAA scientists, CI scientists, and other Regional Consortium scientists to research vessels and laboratory facilities at an "in-house" cost. Regional Consortium members will also voluntarily provide matching funds for postdoctoral and graduate student fellowships sub-awarded to their institution through CIGLR.

B. Senior personnel vitae

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
U. Virginia, Charlottesville, VA	Biology	B.A. 2000
Scripps Inst. of Oceanography, UCSD	Marine Biology	Ph.D. 2006
U. California, Berkeley	Metagenomics	Postdoc 2007-2008

Professional Experience

2021-present	Director, Cooperative Institute for Great Lakes Research
2021-present	Professor, School of Environment and Sustainability, University of Michigan (U-M) (50% appointment)
2021-present	Professor, Dept of Earth & Environmental Sciences, U-M (50%)
2020-2021	Professor, Dept of Earth & Environmental Sciences, U-M
2016-2021	Associate Chair for Curriculum and Undergraduate Studies, Dept of Earth & Environmental Sciences, U-M
2014-2020	Associate Professor, Dept of Earth & Environmental Sciences, U-M
2009-present	Faculty Affiliate, Center for Computational Medicine and Bioinformatics
2008-2014	Assistant Professor, Dept of Earth & Environmental Sciences, U-M

Synergistic Activities

Team Member, NOAA Great Lakes Regional Collaboration Network	2021-present
Member, Data & Bioinformatics Subcommittee, NOAA Omics Working Group	2021-present
Faculty Instructor for The Great Lakes, a summer course for high school students from underrepresented backgrounds.	2020-present
Associate Editor for molecular geomicrobiology, *Geobiology*	2014-2021
Editorial Board, *Environmental Microbiology*	2014-present
Faculty Advisor, Earth Camp, a residential summer camp for high school students from underrepresented backgrounds.	2010-present

Key Honors

2020 John Dewey Award for teaching, College of Literature, Arts, and Sciences, University of Michigan	2020
GSA Geobiology and Geomicrobiology Post-Tenure Award	2020
Individual Award for Outstanding Contributions to Undergraduate Education, College of Literature, Science, and Arts, University of Michigan	2015
Alfred P. Sloan Research Fellow in Ocean Science	2013

Key Peer-Reviewed Publications

Grim, SL, AA Voorhies, BA Biddanda, S Jain, SC Nold, R Green, and **GJ Dick.** (2021). Omics inferred partitioning and expression of diverse biogeochemical functions in a low-O_2 cyanobacterial mat community. *mSystems.* 6:e01042-21.

Dick, G, Duhaime, MB, Evans, JT, Errera, RM, Godwin, C, Kharbush, JJ, Nitzchky, HS, Powers, MA, Vanderploeg, HA, Schmidt, KC, Smith, DJ, Yancy, CE, Zwiers, CC, and VJ Denef. 2021. The genetic and ecophysiological diversity of Microcystis. *Environmental Microbiology*. (https://doi: 10.1111/1462-2920.15615).

Klatt JM, A Chennu, BK Arbic, BA Biddanda, D de Beer, and **GJ Dick** (2021). Possible link between Earth's rotation rate and oxygenation. *Nature Geoscience.* 14:564-570.

Chaffin JD, JF Bratton, EM Verhamme, HB Bair, AA Beecher, CE Binding, JA Birbeck, TB Bridgeman, X Chang, J Crossman, WJS Currie, TW Davis, **GJ Dick**, KG Drouillard, T Frenken, HJ MacIsaac, A McClure, RM McKay, LA Reitz, K Stanislawczyk, RP Stumpf, ZD Swan, BK Snyder, JA Westrick, P Xue, CE Yancey[1], A Zastepa, and X Zhou. (2021). The Lake Erie HABs Grab: A binational collaboration to characterize the western basin cyanobacterial harmful algal blooms at an unprecedented high-resolution spatial scale. *Harmful Algae.* 108:102080.

Dick GJ (2019). The microbiomes of deep-sea hydrothermal vents: distributed globally, shaped locally. *Nature Reviews Microbiology.* 17:271-283.

Kharbush J, DJ Smith, M Powers, HA Vanderploeg, D Fanslow, RL Robinson, **GJ Dick**, and A Pearson. (2019). Chlorophyll nitrogen isotope values track shifts between cyanobacteria and eukaryotic algae in a natural phytoplankton community in Lake Erie. *Organic Geochemistry.* 128:71-77.

Chaffin JD, TW Davis, DJ Smith, MM Baer, and **GJ Dick.** (2018). Interactions between nitrogen form, loading rate, and light intensity on *Microcystis* and *Planktothrix* growth and microcystin production. *Harmful Algae*. 73:84-97.

Dick GJ, SG Grim, and JK Klatt. (2018). Controls on O_2 production in cyanobacterial mats and implications for Earth's oxygenation. *Annual Reviews of Earth and Planetary Sciences.* 46:123-147.

Dick GJ (2018). Genomic Approaches in Earth and Environmental Sciences. Wiley-Blackwell, 12 chapters, 176 pages. *ISBN: 978-1-118-70824-8*

Dick GJ (2017). Embracing the mantra of modelers and synthesizing omics, experiments, and models. *Environmental Microbiology*. 9:18-20.

Meyer KA, TW Davis, SB Watson, VJ Denef, MA Berry, and **GJ Dick.** (2017). Genome sequences of lower Great Lakes Microcystis sp. reveal strain-specific genes that are present and expressed in western Lake Erie blooms. *PLoS One.* 12: e0183859.

Berry M, RM Cory, TW Davis, MB Duhaime, TJ Johengen, GW Kling, JA Marino, PA Den Uyl, D Gossiaux, **GJ Dick**, and VJ Denef. (2017). Cyanobacterial harmful algal blooms are a biological disturbance to Western Lake Erie bacterial communities. *Environmental Microbiology*. 19:1149-1162.

Berry MA, JD White, TW Davis, S Jain, TH Johengen, **GJ Dick**, O Sarnelle, and VJ Denef. (2017). Are oligotypes meaningful ecological and phylogenetic units? A case study of *Microcystis* in freshwater lakes. *Frontiers in Microbiology.* 8:365.

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Education

Institution and Location	Major/Area	Degree & Year(s)
Carleton College	Chemistry	B.A. 2005
University of California, San Diego	Chemistry	Ph.D. 2010
University of British Columbia	Chemistry	Postdoc 2010-2011
University of Iowa	Chemistry	Postdoc 2011-2013

Professional Experience

2021-present	Associate Professor, Department of Chemistry, University of Michigan
2019-2021	Dow Corning Assistant Professor, Department of Chemistry
2013-2019	Assistant Professor, Department of Chemistry
2013-2019	Assistant Professor, Department of Environmental Health Sciences

Synergistic Activities

Initiated and facilities a science communication component for the Detroit Research Internship and Summer Experience (D-RISE) program where students develop "Portal-to-the-Public" activities.	2017-present
Organized a Sloan workshop entitled "Molecular Insights into Chemical Reactions on Indoor Surfaces" May 8, 2018 and featured 15 scholars from across the U.S. and internationally.	2019
Proposal Reviewer for the National Academies of Sciences, Engineering, and Medicines, National Research Corp. Postdoctoral Research Associateship Program (Earth & Atmospheric Sci.).	2017-2018
Elected Board Member of American Association for Aerosol Research	2021-present
Elected Chair, Aerosol Chemistry Group, American Association for Aerosol Research	2017-2018

Key Honors

University of Michigan Department of Chemistry, Dow Corning Assistant Professor	2019-2021
"Top 40 Under 40" Power List by the Analytical Scientist	2018
Sloan Research Fellow – Chemistry	2018
CAREER Award from National Science Foundation Chemistry Division	2017
Atmospheric Chemistry Colloquium for Emerging Senior Scientists (ACCESS), selected participant	2013

Key Peer-Reviewed Publications

Olson, NE, ME Cooke, J Shi, JA Birbeck, JA Westrick, and **AP Ault.** (2020). Harmful Algal Bloom Toxins in Aerosol from Freshwater Lakes. *Environmental Science & Technology*. 54(8):4769-4780.

Olson, NE, NW May, RM Kirpes, AE Watson, KD Hajny, JH Slade, PB Shepson, BH Stirm, KA Pratt, and **AP Ault.** (2019). Lake Spray Aerosol Incorporated in to Great Lakes Clouds. *ACS Earth and Space Chemistry*. 3(12):2765-2774.

May, NW, MJ Gunsch, NE Olson, AL Bondy, RM Kirpes, SB Bertman, C Swarup, A Laskin, PK Hopke, **AP Ault,** and KA Pratt. (2018). Unexpected contributions of sea spray and lake spray aerosol to inland particulate matter. *Environmental Science and Technology Letters*, 2018, 5(7):405–412.

May, NW, NE Olson, M Panas, JL Axson, PS Tirella, RM Kirpes, RL Craig, MJ Gunsch, S China, A Laskin, **AP Ault,** and KA Pratt. (2018). Aerosol Emissions from Great Lakes Harmful Algal Blooms. *Environmental Science & Technology*. 52(2):397–405.

May, N, JL Axson, A Watson, KA Pratt, and **AP Ault.** (2016). Lake Spray Aerosol Generation: A Method for Producing Representative Particles from Freshwater Wave Breaking. *Atmospheric Measurement Techniques*. 9(9):4311–4325.

Pye, HOT, A Nenes, B Alexander, **AP Ault,** M Barth, S Clegg, JL Collett, KM Fahey, CJ Hennigan, H Herrmann, M Kanakidou, J Kelly, I-Ting Ku, VF McNeill, N Riemer, T Schaefer, G Shi, A Tilgner, JT Walker, T Wang, R Weber, J Xing, R Zaveri, and A Zuend. (2020). The Acidity of Atmosphere Particles and Clouds. *Atmospheric Chemistry & Physics.* 20:4809-4888.

Kirpes, RM, D Bonanno, NW May, M Fraund, AJ Barget, RC Moffet, **AP Ault,** KA and Pratt. (2019). Wintertime Arctic sea spray aerosol composition controlled by sea ice lead microbiology. *ACS Central Science*. 5(11):1760-1767.

Craig, RL, PK Peterson, L Nandy, Z Lei, MA Hossain, S Camarena, RA Dodson, RD Cook, CS Dutcher, and **AP Ault.** (2018). Direct Determination of Aerosol pH: Size-Resolved Measurements of Submicron and Supermicron Aqueous Particles. *Analytical Chemistry*. 90(19):11232–11239.

Axson, JL, NW May, ID Colon-Bernal, KA Pratt, and **AP Ault.** (2016). Lake Spray Aerosol: A Chemical Signature from Individual Ambient Particles. *Environmental Science and Technology*. 50(18):9835–9845.

Rindelaub, JD, RL Craig, L Nandy, AL Bondy, CS Dutcher, PB; Shepson, and **AP Ault.** (2016). Direct Measurement of pH in Individual Particles via Raman Microspectroscopy and Variation in Acidity with Relative Humidity. *Journal of Physical Chemistry – A*. 120(6):911–917.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
KU Leuven, Belgium	Biological Engineering	B.S. 1999
KU Leuven, Belgium	Biological Engineering	M.Eng. 2001
Universiteit Gent, Belgium	Applied Biological Sciences	Ph.D. 2005
Michigan State University, MI	Environmental Microbiology	Visiting Scholar, 2001-2005
U. California, Berkeley, CA	Molecular Microbial Ecology	Postdoc 2005-2011

Professional Experience

2020-present	Associate Professor, Dept of Ecology and Evolutionary Biology, University of Michigan, Ann Arbor, MI
2012-2020	Assistant Professor, Dept of Ecology and Evolutionary Biology, University of Michigan, Ann Arbor, MI
2008-2008	Teaching Staff, NSF Antarctic Biology Course, McMurdo Station

Synergistic Activities

Editorial Board for *Microbiology Spectrum (ASM Journals)*	2021-present
Teaching team member for the interdisciplinary biology M-Sci class for incoming students (2016-current) aimed at increasing retention and diversity in STEM majors.	2016-present
Departmental Faculty Ally, intersection of graduate student support and DEI	2021-present
Departmental JEDI committee, Chair	2019-2021

Key Honors

Teaching Excellence Award (University of Michigan Program in Biology)	2019

Key Peer-Reviewed Publications

Dick, G, MB Duhaime, JT Evans, RM Errera, C Godwin, JJ Kharbush, HS Nitzchky, MA Powers, HA Vanderploeg, KC Schmidt, DJ Smith, CE Yancy, CC Zwiers, and **VJ Denef.** (2021). The genetic and ecophysiological diversity of *Microcystis*. *Environmental Microbiology*. (DOI:10.1111/1462-2920.15615).

Jackrel, SL, JW Yang, KC Schmidt, and **VJ Denef**. (2021). Host specificity of microbiome assembly and its fitness effects in phytoplankton. *ISME J*. 15:774–788.

Schmidt, KC, SL Jackrel, DJ Smith, GJ Dick, and **VJ Denef**. (2020). Genotype and host microbiome alter competitive interactions between *Microcystis aeruginosa* and *Chlorella sorokiniana*. *Harmful Algae.* 99, 101939.

Props, R, N Boon, and **VJ Denef**. (2020). Strain-resolved analysis of a ubiquitous and abundant freshwater bacterial lineage shows larger genomic divergence across nutrient than temperature gradients. *Appl. Env. Microbiol.* 86(10) e00140-20. [AEM Spotlight Article].

Jackrel, SL, K Schmidt, BJ Cardinale, and **VJ Denef**. (2020). Microbiomes Reduce their Host's Sensitivity to Interspecific Interactions. *mBio.* 11:e02657-19 [mBio Editor's pick].

Jackrel, SL, J White, K Buffin, K Hayden, O Sarnelle, and **VJ Denef**. (2019). Genome Evolution and Host Microbiome Shifts Correspond with Intraspecific Niche Divergence within Harmful Algal Bloom-Forming *Microcystis aeruginosa*. *Mol Ecol*. 28(17):3994-4011. [Mol Ecol blog spotlight article]

Denef, VJ (2018). Peering into the Genetic Makeup of Natural Microbial Populations Using Metagenomics. Martin F. Polz and Om P. Rajora (eds.), *Population Genomics: Microorganisms* (Springer). (DOI:10.1007/13836_2018_14).

Props, R, ML Schmidt, J Heyse, HA Vanderploeg, N Boon, and **VJ Denef**. (2018). Flow cytometric monitoring of bacterioplankton phenotypic diversity predicts high population-specific feeding rates by invasive dreissenid mussels. *Environ Microbiol.* 20(2):521-534.

Denef VJ, HJ Carrick, J Cavaletto, E Chiang, TH Johengen, and HA Vanderploeg. (2017). Lake bacterial assemblage composition is sensitive to biological disturbance caused by an invasive filter feeder. *mSphere.* 2(3), e00189-17.

Meyer, KA, TW Davis, SB Watson, **VJ Denef,** MA Berry, and GJ Dick. (2017). Genome sequences of lower Great Lakes Microcystis sp. reveal strain-specific genes that are present and expressed in western Lake Erie blooms. *PloS One.* 12(10), e0183859.

Berry, MA, JD White, TW Davis, S Jain, TH Johengen, GJ Dick, O Sarnelle, and **VJ Denef**. (2017). Are oligotypes meaningful ecological and phylogenetic units? A case study of Microcystis in freshwater lakes. *Front Microbiol*. 8:365.

Berry, MA, TW Davis, RM Cory, MB Duhaime, TH Johengen, GW Kling, JA Marino, PA Den Uyl, D Gossiaux, GJ Dick, and **VJ Denef**. (2017). Cyanobacterial harmful algal blooms are a biological disturbance to western Lake Erie bacterial communities. *Environ Microbiol*. 19(3):1149-1162.

Fujimoto, M, J Cavaletto, JR Liebig, A McCarthy, HA Vanderploeg, and **VJ Denef**. (2016). Spatiotemporal distribution of bacterial populations along a freshwater estuary to pelagic gradient in Lake Michigan. *J Great Lakes Res.* 42:1036-1048.

Denef, VJ, RS Mueller, E Chiang, JR Liebig, and HA Vanderploeg. (2016). Chloroflexi CL500-11 populations that predominate deep lake hypolimnion bacterioplankton rely on nitrogen-rich DOM metabolism and C1 compound oxidation. *Appl Env Microbiol.* 82(5):1423-32 [AEM spotlight article].

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
U. California, Santa Barba	Environ Science & Management	Ph.D. 2001
Michigan State University	Fisheries and Wildlife	M.Sc. 2006
Michigan State University	Fisheries and Wildlife	B.Sc. 2004

Professional Experience

2019-present	Assistant Professor of Environmental Policy and Planning, School for Environment and Sustainability, University of Michigan
2015-2019	Assistant Professor of Urban Politics, Department of Political Science, University of Toronto, Mississauga and Toronto, Ontario

Synergistic Activities

Member, Great Lakes Regional Water Infrastructure Working Group of the Great Lakes Commission	2021-present
Member, Water Conservation and Affordability Working Group, Detroit Water and Sewerage Department	2020-present
Chapter Lead Author, United Nations Environment Program's Global Environmental Outlook (GEO) Cities Report	2019-present
Chapter Lead Author, U.S. Global Change Research Program's Second State of the Carbon Cycle Report	2019-present
Chapter Lead Author, Second Assessment Report of the Urban Climate Change Research Network	2018-present

Key Honors

Bissell-Heyd Fellowship, University of Toronto	2016-2017
Clarence Stone Young Scholar Award, American Political Science Association	2013
CALFED Science Program Pre-Doctoral Research Fellowship	2008-2010
Fulbright Postgraduate Fellowship, University of Adelaide, Australia	2007-2008

Key Peer-Reviewed Publications

Hughes, S and A Dick. *Forthcoming*. A Multi-Dimensional Approach to Evaluating the Vulnerability of Drinking Water Systems. *Journal of Environmental Policy and Planning.*

Hughes, S, A Dick, and A Kopec. (2021). "Municipal Takeovers: Examining State Discretion and Local Impacts in Michigan." *State and Local Government Review.* (DOI:10.1177/0160323X211038862).

Hughes, S, S Dobie, K Schwarz, GL LeMee, M Lane, and A Gonzalez. *Forthcoming*. "Centering Racial Justice in Urban Flood Resilience Policy and Planning: Tools for practitioners and stakeholders," *Environmental Justice.*

Hughes, S, S Giest, and L Tozer. (2020). "Accountability and Data-Driven Urban Climate Governance," *Nature Climate Change.* 10:1085-1090.

Hughes, S. (2020). "Flint, Michigan and the Politics of Safe Drinking Water in the US," *Perspectives on Politics.* First View, pp. 1-14. (DOI:10.1017/S153759272000136X).

Hughes, S. (2020). "Principles, Drivers, and Policy Tools for Just Climate Change Adaptation in Legacy Cities." *Environmental Science and Policy.* Vol. 111, pp. 35-41.

Carlson, A, W Taylor, and **S Hughes**. (2020). "The Metacoupling Framework Informs Stream Salmonid Management and Governance," *Frontiers in Environmental Science.* 8:27. (DOI:10.3389/fenvs.2020.00027).

Hughes, S and M Hoffmann. (2020). "Just Urban Transitions: Toward a Research Agenda." *WIREs Climate Change.* e640. (DOI:10.1002/wcc.640).

Hughes, S. (2019). *Repowering Cities: Governing Climate Change Mitigation in New York City, Los Angeles, and Toronto.* Cornell University Press.

Hughes, S, E Chu, and S Mason (Eds.). (2018). *Climate Change in Cities: Innovations in Multilevel Governance*. Springer.

Hughes, S, DM Runfola, and B Cormier. (2018). "Issue Proximity and Policy Response of Local Governments." *Review of Policy Research.* 35(2):192-212.

Patterson, JJ, T Thaler, M Hoffmann, **S Hughes**, A Oels, E Chu, A Mert, D Huitema, S Burch, and A Jordan. (2018). "Political Feasibility of 1.5°C Societal Transformations: The Role of Social Justice," *Current Opinion in Environmental Sustainability.* 31:1-9.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
Aachen U. of Technology (RWTH Aachen), Germany	Physics	Vordiplom, (B.A.) 1994
U. of Bonn, Germany	Meteorology	Diplom, (M.S.) 1998
U. of Michigan, Ann Arbor, MI	Atmospheric & Space Sciences & Scientific Computing	Ph.D. 2004
National Center for Atmospheric Research (NCAR), Boulder, CO	Atmospheric Modeling	Postdoc 2004-2006

Professional Experience

9/2021-present	Professor, University of Michigan, Department of Climate and Space Sciences and Engineering (CLASP), Ann Arbor
9/2012-8/2021	Associate Professor, CLASP, University of Michigan, Ann Arbor
9/2006-8/2012	Assistant Professor, CLASP, University of Michigan, Ann Arbor
3/2006-8/2006	Research Fellow, CLASP, University of Michigan, Ann Arbor, MI and Visiting Scientist, NOAA Geophysical Fluid Dynamics Laboratory (GFDL), Princeton, NJ
3/2004-2/2006	Postdoctoral Fellow, NCAR, Advanced Study Program
11/1997-2/1998	Consultant, European Centre for Medium-Range Weather Forecasts, U.K.

Synergistic Activities

University partner of a NOAA-wide Research-to-Operations (R2O) project that advances the operational readiness of NOAA's new weather and climate Unified Forecast System (UFS)	2020-present
Member of the Scientific Steering Committee for NCAR's Community Earth System Model (CESM) and co-chair of CESM's Atmosphere Model Working Group (AMWG)	2019-present 2014-present
Member of the NOAA Developmental Testbed Center (DTC) Science Advisory Board	2020-present
Member of the American Meteorological Society (AMS) Committee on Artificial Intelligence Applications to Environmental Science	2019-present
Key organizer of the atmospheric science/modeling workshop series *Physics-Dynamics Coupling* (PDC) the international Dynamical Core Model Intercomparison Project (DCMIP)	2014, '16, '18, '22 2008, 2012, 2016

Key Honors

Presidential Early Career Award for Scientists and Engineers (PECASE)	2011
Department of Energy Early Career Award	2010

Key Peer-Reviewed Publications

Toniazzo, T, M Bentsen, C Craig, B Eaton, J Edwards, S Goldhaber, **C Jablonowski**, and P Lauritzen. (2020). Enforcing conservation of axial angular momentum in the atmospheric general circulation model CAM6. *Geosci. Model Dev.* 13:685–705.

Limon, G and **C Jablonowski**. (2020). An Assessment of Machine Learning Techniques for Replicating Physical Forcing Mechanisms in Climate Models, Earth and Space Science. Open Archive. (DOI:10.1002/essoar.10501799.1). (online archive).

Zarzycki, CM, **C Jablonowski**, J Kent, PH Lauritzen, R Nair, KA Reed, PA Ullrich, DM Hall, D Dazlich, R Heikes, C Konor, D Randall, X Chen, L Harris, M Giorgetta, D Reinert, C Kühnlein, R Walko, V Lee, A Qaddouri, M Tanguay, H Miura, T Ohno, R Yoshida, SH Park, J Klemp, and W Skamarock. (2019). DCMIP2016: The Splitting Supercell Test Case. *Geosci. Model Dev.* 12:879–892.

Ferguson, JO, **C Jablonowski**, and H Johansen. (2019). Assessing Adaptive Mesh Refinement (AMR) in a Forced Shallow-Water Model with Moisture. *Mon. Wea. Rev*. 147:3673–3692.

Gross, M, H Wan, PJ Rasch, PM Caldwell, DL Williamson, D Klocke, **C Jablonowski**, DR Thatcher, N Wood, M Cullen, B Beare, M Willett, F Lemarie, E Blayo, S Malardel, P Termonia, P Bechtold, A Gassmann, PH Lauritzen, H Johansen, CM Zarzycki, K Sakaguchi, and R Leung. (2018). Physics–Dynamics Coupling in weather, climate and Earth system models: Challenges and recent progress. *Mon. Wea. Rev*. 146:3505-3544.

Ullrich, PA, **C Jablonowski**, J Kent, PH Lauritzen, R Nair, KA Reed, CM Zarzycki, DM Hall, D Dazlich, R Heikes, C Konor, D Randall, T Dubos, Y Meurdesoif, X Chen, L Harris, C Kühnlein, V Lee, A Qaddouri, C Girard, M Giorgetta, D Reinert, J Klemp, SH Park, W Skamarock, H Miura, T Ohno, R Yoshida, R Walko, A Reinecke, and K Viner, (2017). DCMIP2016: A Review of Non-hydrostatic Dynamical Core Design and Intercomparison of Participating Models. *Geosci. Model Dev*. 10:4477-4509.

Bosler, PA, J Kent, R Krasny, and **C Jablonowski**. (2017). A Lagrangian Particle Method with Remeshing for Tracer Transport on the Sphere. *J. Comput. Phys*. 340:639-654.

Ferguson, JO, **C Jablonowski**, H Johansen, P McCorquodale, P Colella, and PA Ullrich. (2016). Analyzing the Adaptive Mesh Refinement (AMR) characteristics of a high-order 2D cubed-sphere shallow-water model. *Mon. Wea. Rev.* 144:4641–4666.

Zarzycki, CM, **C Jablonowski**, DR Thatcher, and MA Taylor. (2015). Effects of localized grid refinement on the general circulation and climatology in the Community Atmosphere Model. *J. Climate*. 28:2777-2803.

Ullrich, PA and **C Jablonowski.** (2012). MCore: A Non-hydrostatic Atmospheric Dynamical Core Utilizing High-Order Finite-Volume Methods. *J. Comput. Phys.* 231:5078-5108.

Jablonowski, C, RC Oehmke, and QF Stout. (2009). Block-structured Adaptive Meshes and Reduced Grids for Atmospheric General Circulation Models. *Philosophical Transactions of the Royal Society A.* 367:4497-4522.

Jablonowski, C, M Herzog, JE Penner, RC Oehmke, QF Stout, B van Leer, and KG Powell. (2006). Block-Structured Adaptive Grids on the Sphere: Advection Experiments. *Mon. Wea. Rev.* 134:3691-3713.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
Michigan State U., East Lansing, MI	Biology	B.Sc. 1981
Florida State U., Tallahassee, FL	Oceanography	M.Sc. 1986
U. of Michigan, Ann Arbor, MI	Oceanic Science	Ph.D. 1991

Professional Experience

2019-present	Director, Michigan Sea Grant, University of Michigan
2015-present	Research Scientist, CIGLR, SEAS, University of Michigan
2006- present	Chief Scientist, Alliance for Coastal Technologies.
2020-2021	Acting Director, CIGLR, University of Michigan
2009- 2019	Associate Director, CILER (CIGLR), SEAS, University of Michigan.
2009-2015	Associate Research Scientist, CILER, SNRE, University of Michigan
2000-2005	Director, CILER, SNRE, University of Michigan.
1997-2009	Assistant Research Scientist, CILER, University of Michigan.

Synergistic Activities

Chief Scientist for the Alliance for Coastal Technologies	2006-present
Board member of Canadian Aquatic Invasive Species Network II	2012-2016
Committee member of Great Lakes Aquatic Nuisance Species Panel	2001-2018
Co-Chair of 48th annual conference of International Association for Great Lakes Research, Board member of International Association for Great Lakes Research	2002-2005

Key Honors

IOOS-GLOS: Special Achievement Award	Nov 2013
University of Michigan: Research Faculty Achievement Award	May 2013
IAGLR: Chandler-Misener Award for 2008 Best Paper in JGLR	May 2009
NOAA-OAR : Outstanding Scientific Paper Award	Sept 2008

Key Peer-Reviewed Publications

Anderson, HS, **TH Johengen**, CM Godwin, H Purcell, PJ Alsip, SA Ruberg, and LA Mason. (2021). Continuous in situ Nutrient Analyzers Pinpoint the Onset and Rate of Internal P Loading under Anoxia in Lake Erie's Central Basin, *ACS ES&T Water*. (DOI:10.1021/acsestwater.0c00138).

Liu, Q, MD Rowe, EJ Anderson, CA Stow, RP Stumpf, and **TH Johengen.** (2020). Probabilistic forecast of microcystin toxin using satellite remote sensing, in situ observations and

numerical modeling. *Environmental Modelling and Software*. 128. (DOI:10.1016/j.envsoft.2020.104705).

Rowland, FE, CA Stow, **TH Johengen**, AM Burtner, D Palladino, DC Gossiaux, TW Davis, LT Johnson, and SA Ruberg. (2019). Recent patterns in Lake Erie phosphorus concentrations in response to changing loads. *Environmental Science and Technology.* 54(2):835-841. (DOI:10.1021/acs.est.9b05326).

Guo, T, D Gill, **TH Johengen**, and B Cardinale. (2019). What determines the public's support for water quality regulations to mitigate agricultural runoff? *Environmental Science and Policy.* 101:323-330.

Kitchens, C, **TH Johengen,** and TW Davis. (2018). Establishing spatial and temporal patterns in Microcystis sediment seed stock viability and their relationship to subsequent bloom development in Western Lake Erie. *PLoS ONE*. 13(11): e0206821. (https://doi.org/10.1371/journal. pone.0206821).

First, MR, LA Drake, V Molina, CS Moser, SH Robbins-Whitney, SC Riley, EN Buckley, AA Cangelosi, KJ Carney, **TH Johengen**, H Purcell, ED Reavie, GJ Smith, and MN Tamburri. (2018). A test of the framework designed to evaluate compliance monitoring devices for ballast water discharge. *Management of Biological Invasions*. 9(4):505-513. (https://doi.org/10.3391/mbi.2018.9.4.13).

Gobler, CJ, JM Burkholder, TW Davis, MJ Harke, **TH Johengen**, CA Stow, and DB Van de Waal. (2016). The dual role of nitrogen supply in controlling the growth and toxicity of cyanobacterial blooms. *Harmful Algae*. 54:87-97.

Bunnell, DB, RP Barbiero, SA Ludsin, CP Madenjian, GJ Warren, DM Dolan, TO Brenden, R Briland, OT Gorman, JX He, **TH Johengen**, BF Lantry, BM Lesht, TF Nalepa, SC Riley, CM Riseng, TJ Treska, I Tsehaye, DM Warner, MG Walsh, and BC Weidel. (2014). Changing ecosystem dynamics in the Laurentian Great Lakes: exploring evidence for bottom-up and top-down regulation. *BioScience*. 64(1):26-39.

Michalak, AM, EJ Anderson, D Beletsky, S Boland, NS Bosch, TB Bridgeman, JD Chaffin, K Cho, R Confesor, I Daloglu, JV DePinto, MA Evans, GL Fahnenstiel, L He, JC Ho, L Jenkins, **TH Johengen**, KC Kuo, E LaPorte, X Liu, MR McWilliams, MR Moore, DJ Posselt, RP Richards, D Scavia, AL Steiner, E Verhamme, DM Wright, and MA Zagorski. (2013). Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions. *PNAS*. 110(16): (DOI:10.1073/pnas.1216006110).

Johengen, TH, Vanderploeg, HA, and JR Liebig. (2013). Effects of algal composition, seston stoichiometry, and feeding rate on zebra mussel (Dreissena polymorpha) nutrient excretion in two Laurentian Great Lakes. *In Quagga and Zebra Mussels: Biology, Impacts, and Control, Second Edition.* T.F. Nalepa, and D.W. Schlosser (Eds.). CRC Press, Boca Raton, FL, 445-459.

Johengen, TH, BA Biddanda, and JB Cotner. (2008). Stimulation of Lake Michigan plankton metabolism by sediment resuspension and river runoff. Journal of Great Lakes Research. 34:213-227.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
U. of Florida, Gainesville	Civil Engineering	B.S. 2007
U. of California, Berkeley	Civil & Environmental Engineering	M.S. 2008
U. of California, Berkeley	Electrical Engineering & Computer Science	M.S. 2012
U. of California, Berkeley	Civil & Environmental Engineering	Ph.D. 2012

Professional Experience

2021-present	*Arthur F. Thurnau Associate Professor*
2019-present	*Associate Professor*, University of Michigan
2013-2019	*Assistant Professor*, University of Michigan
2012 – 2020	*Founder*, CTO, Metronome Systems

Synergistic Activities

Core contributor to various open source initiatives, including Open-Storm.org and OpenWSN. Founded open-storm.org as an open-source and educational initiative for the sensing and control of urban water systems.

Co-organizer and host of the 2017 Water Environment Foundation international workshop on "Big Data in Stormwater." Hosted nearly fifty participants from various countries to share studies and discuss the frontiers of the sensing and real-time contrl of stormwater systems.

Regularly volunteer to offer weeklong workshop on sensors, data acquisition, and wireless sensor networks for water systems. I organized this workshop in 2014 and 2017 for the Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI).

Founder, Engineers without Borders, University of Florida Chapter (2006-2008). Founded chapter while leading the fundraising and management of multiple local and international projects.

Key Honors

National Academy of Engineering Gilbreth Lecturer	2018
Grand Prize WEF/WRF Intelligent Water Challenge	2018
ES&T, Feature of the Year Paper Award	2017
1938E Award, UM College of Engineering	2018
Berker and Gokyigit Faculty Scholar UM	2014
NSF CAREER Award, National Science Foundation	2018
Chi Epsilon James M. Robbins Excellence in Teaching	2018
CUAHSI Water Drop Award	2018
Ten Technology Leaders Under 40, Connected World	2017
CEE Professors of the Year	2014, 2018

Key Peer-Reviewed Publications

Bartos MD and **B Kerkez**. (2021). “Pipedream: An interactive digital twin model for natural and urban drainage systems.” *Environmental Modeling & Software*.

Mason B and B **Kerkez**. (2021). “StormReactor: An open-source Python package for the integrated modeling of urban water quality and water balance.” *Environmental Modeling & Software*.

Bartos MD and **B. Kerkez.** (2021). “Observability-based sensor placement improves contaminant tracing in river networks.” *Water Resources Research.*

Martinez, Paz E, M Tobias, E Escobar, L Raskin, E Roberts, K Wigginton, and **B Kerkez.** (2021). “Wireless Sensors for Measuring Drinking Water Quality in Building Plumbing: Deployments and Insights from Continuous and Intermittent Water Supply Systems.” *ACS ES&T Engineering.*

Mullapudi, A, BP Wong, MD Bartos, and **B Kerkez**. (2018). "Shaping streamflow using a real-time stormwater control network." *Sensors*.

Mullapudi, A, MJ Lewis, CL Gruden, and **B Kerkez**. (2020). Deep reinforcement learning for the real time control of stormwater systems. *Advances in Water Resources*.

Fries, KJ and **B Kerkez**. (05/2018). "Using sensor data to dynamically map large-scale models to site-scale forecasts: A case study using the National Water Model." *Water Resources Research*.

Bartos, MD, BP Wong, and **B. Kerkez**. (2018). "Open-storm: a complete framework for the measurement and control of urban water systems." *Environmental Science: Water Research & Technology*.

Troutmat, SC, NG Love, and **B. Kerkez.** (2020). "Balancing water quality and flows in combined sewer systems using real-time control." E*nvironmental Science: Water Research & Technology*.

Bartos, MD, H Park, T Zhou, **B Kerkez**, and R Vasudevan. (01/2019). "Vehicles as sensors: high accuracy precipitation maps from windshield wiper measurements." *Nature, Scientific Reports*.

Bartos MD and **B Kerkez**. (01/2019). "Hydrograph peak-shaving using a graph-theoretic algorithm for placement of hydraulic control structures." *Advances in Water Resources*.

Habibi, H, I Dasgupta, S Noh, S Kim, M Zink, DJ Seo, MD Bartos, and **B Kerkez**. (01/2019). "High-Resolution Hydrologic Forecasting for Very Large Urban Areas." *Journal of Hydroinformatics*.

Bartos, MD and **B Kerkez**. (2019). "Hydrograph peak-shaving using a graph-theoretic algorithm for placement of hydraulic control structures." *Advances in Water Resources*.

Habibi, H, I Dasgupta, S Noh, S Kim, M Zink, DJ Seo, MD Bartos and B Kerkez. (2019). "High-resolution hydrologic forecasting for very large urban areas." *Journal of Hydroinfromatics*.

Hu, Y, L Colleen, Y Wang, D Scavia, and B Kerkez. (2019). "Urban total phosphorus loads to the St. Clair-Detroit River System." *Journal of Great Lakes Research*.

Persuad, P, AA Akin, **B Kerkez**, DT McCarthy, and JM Hathaway. (2019). "Real time control schemes for improving water quality from bioretention cells." *Blue Green Systems*.

Wong, BP and **B Kerkez**. (09/2018). "Real-time control of urban headwater catchments through linear feedback: performance, analysis and site selection." *Water Resources Research*.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
Universidade Federal de Juiz de Fora – UFJF (Brazil)	Economics	B.S.
Massachusetts Institute of Technology – MIT	Political Sci	M.Sc.
Massachusetts Institute of Technology - MIT	Political Sci	Ph.D.
The University of Arizona	Latin Am. Studies	Postdoc

Professional Experience

2015 – 2020	Associate Dean for Research and Engagement: School for Environment and Sustainability
2012- Present	Professor School for Environment and Sustainability—University of Michigan
2012- Present	Professor, Program of the Environment—University of Michigan
2006 – 2012	Associate Professor of Natural Resources and Environment, School of Natural Resources and Environment—University of Michigan
2002 – 2005	Assistant Professor of Natural Resources and Environment, School of Natural Resources and Environment—University of Michigan
2001 – 2002	Assistant Professor of Latin American Studies, Latin American Area Center - The University of Arizona, Tucson, AZ
1998 – 2001	Assistant Research Professor, Latin American Area Center - The University of Arizona, Tucson, AZ Senior Scholar, Udall Center for Studies in Public Policy, University of Arizona

Synergistic Activities

PI and Co-Director of GLISA—the Great Lakes Integrated Science & Climate Assessments funded by NOAA	Present
IPCC AR-5 Lead Author (WGII Chapter 20: Climate Resilient Pathways), contributing author AR4 (vol. II Chapter 13)	Present
Co-author for the Fourth National Climate Assessment (NCA4) Midwest Chapter	2018
Member of the US Federal Committee on Sustained Climate Assessment, NOAA	2016-17
Member of the following National Academy of Sciences Committees and Boards: Strategic Advice to the Climate Change Science Program Committee	2006-08
"Advancing the Science of Climate Change"	2010
America's Climate Choices"	2009-10
Board of Environment Change and Society	2008-2013
U.S. Global Change Research Program (USGCRP) Committee	2011-13
Social Experts Action Network (SEAN)	2021-present

Member NSF Advisory Committee to the President on Environmental Research and Education (AC-ERE). National Science Foundation — 2015-2021

Key Honors

James Martin 21st Century School Fellowship, Environmental Change Institute, Oxford University, England — July 2006-07

Kavli Fellow, US National Academy of Sciences — 2007

Certificate of Tribute by Governor Jennifer M. Grandholm (Michigan) to honor contributions to the science of global climate change" in conjunction with "the Intergovernmental Panel on Climate Change (IPCC) — 2008

National Science Foundation Distinguished Lecture. "Building Adaptive Capacity to Climate Change." Washington DC — 0312/2015

The Governor's Award for Environmental Excellence. Office of the Governor, Indiana. U2U—for Useful to Usable project (USDA)

Key Peer-Reviewed Publications

Lu, J, **MC Lemos** *et al*. (2021). Scaling up co-produced climate-driven decision support tools for agriculture. *Nature Sustainability.*

Treuer, G, C Kirchhoff, **MC Lemos** & F McGrath. (2021). Challenges of managing harmful algal blooms in US drinking water systems. *Nature Sustainability*. pp.1-7.

Briley, L, R Kelly, ED Blackmer, AV Troncoso, RB Rood, J Andresen, & **MC Lemos**. (2020). Increasing the Usability of Climate Models through the Use of Consumer-Report-Style Resources for Decision-Making, *Bulletin of the American Meteorological Society*. 101(10):E1709-E1717.

Lemos, MC, J Arnott et al. (2018). "To co-produce or not to co-produce." *Nature Sustainability.* 1**:**722–724.

Rasmussen, LV, CJ Kirchhoff, and **MC Lemos**. (2017). "Adaptation by stealth: climate information use in the Great Lakes region across scales." *Climatic Change*. 1-15.

Lemos, MC, CJ Kirchhoff, SE Kalafatis, D Scavia, & RB Rood. (2014). "Moving climate information off the shelf: Boundary Chains and the role of RISAs as adaptive organizations." *Weather, Climate, and Societ*y. 6(2):273-285. https://journals.ametsoc.org/view/journals/bams/101/10/bamsD190099.xml

Morrison, TH, WN Adger, K Brown, M Hettiarachchi, C Huchery, **MC Lemos** & TP Hughes. (2020). Political dynamics and governance of World Heritage ecosystems. *Nature Sustainability.* 3**:**947-955.

Morrison TH, TP Hughes, WN Adger, K Brown, J Barnett, & **MC Lemos**. (2019). Save reefs to rescue all ecosystems. *Nature*. 573(7774):333-36.

Morrison TH, WN Adger, K Brown, **MC Lemos**, D Huitema….J Phelps. (2020). The blackbox of power in polycentric environmental governance. *Global Environmental Change.* 57.

Lemos, MC, C Kirchhoff, and V Ramparasad. (2012). Narrowing the Climate Information Usability Gap. *Nature Climate Change*. 2(11):789-94.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
College of Wooster, Wooster, OH	Biology	B.A. 1984
Duke University, Durham, NC	Environmental Management	M.E.M. 1987
Duke University, Durham, NC	Public Policy Studies	M.A. 1987
U. of North Carolina, Chapel Hill, NC	Law	J.D. 1998
U. of North Carolina, Chapel Hill, NC	City & Regional Planning	Ph.D. 2001

Professional Experience

2017 – Present	Co-P.I., Cooperative Institute for Great Lakes Research
2018 – 2020	Dow Faculty Fellow, Graham Sustainability Institute, UM
2015 – Present	Professor, Urban and Regional Planning Program, UM
2015 – Present	Professor, Program in the Environment, UM
2010 – 2017	Chair, Urban and Regional Planning Program, UM
2010 – 2015	Executive Committee, Graham Sustainability Institute, UM
2009 – Present	Faculty Affiliate, Graham Sustainability Institute, UM
2008 – 2015	Associate Professor, Urban and Regional Planning Program, UM
2008 – 2015	Associate Professor, Program in the Environment, UM
2007 – 2011	Faculty Fellow, Michigan Memorial Phoenix Energy Institute, UM
2001 – 2008	Assistant Professor, Urban and Regional Planning Program, UM
2003 – 2008	Faculty Associate, Program in the Environment, UM
2000 – 2001	Research Associate, Env. Finance Cntr, U. of North Carolina, Chapel Hill
1991 – 1994	Environmental Policy Analyst and Planner, CH2M Hill, Oakland, CA
1987 – 1991	Environmental Policy Analyst, ICF Incorporated, Fairfax, VA

Synergistic Activities

Editorial Board, *Michigan Journal of Community Service Learning*	2021 – present
President, International Academic Association on Planning, Law, and Property Rights (PLPR)	2016 – 2020
Vice President, PLPR	2014 – 2016
Faculty Lead, *Michigan Engaging Community through the Classroom* Multi-Disciplinary, Community-Engaged Teaching Initiative	2013 – present
Editorial Board, *Journal of Planning Education and Research*	2012 – present
Board of Directors, Michigan Land Information Access Association (LIAA)	2007 – 2016
Planning Law Committee, Michigan Association of Planning	2004 – present
Board of Directors, Huron River Watershed Council	2002 – present

Key Honors

Gala/Michigan Sustainability Cases Innovation Award	2020
Provost's Teaching Innovation Prize	2015
Faculty Service Award (awarded by graduating MURP students)	2011, 2012, 2013
Outstanding Volunteer of the Year Award, Michigan Association of Planning	2005, 2006
Science to Achieve Results (STAR) Graduate Fellowship, U.S. EPA	1997 – 2000
Dissertation Fellowship Award, Lincoln Institute for Land Policy	1999

Key Peer-Reviewed and Law Journal Publications

Norton, RK (2020). Dynamic coastal shoreland zoning: Adapting fastland zoning for naturally shifting coastal shores. *Zoning Practice.* 37(3):1-7.

Sadiq, AA, J Tyler, DS Noonan, **RK Norton,** SE Cunniff, & J Czajkowski. (2020). Review of the Federal Emergency Agency's Community Rating System Program. *Natural Hazards Review.* 21(1):03119001. (online, https://DOI/10.1061/(ASCE)NH.1527-6996.0000320.).

Norton, RK, S Buckman, G Meadows, & Z Rable. (2019). Using simple, decision-centered, scenario-based planning to improve local coastal management. *Journal of the American Planning Association.* 85(4):405-423.

Norton, RK & NH Welsh. (2019). Reconciling police power prerogatives, public trust interests, and private property rights along Laurentian Great Lakes shores. *Michigan Journal of Environmental and Administrative Law.* 8(2):409-476.

Norton, RK, NP David, S Buckman, & PD Koman. (2018). Overlooking the coast: Limited local planning along Michigan's Great Lakes shores. *Land Use Policy.* 71:183-203.

Norton, RK (2014). Agenda 21 and its discontents: Is sustainable development a global imperative or globalizing conspiracy? *The Urban Lawyer.* 46(2):325-360.

Norton, RK & GA Meadows. (2014). Land and water governance on the shores of the Laurentian Great Lakes. *Water International.* 39(6):901-920.

Norton, RK, LA Meadows, & GA Meadows. (2014). What if (inland) sea levels are falling…then rising…then falling? Global climate change and shoreland management on the Laurentian Great Lakes. *Geography Forum Review.* 34:59-73.

Norton, RK, GA Meadows, & LA Meadows. (2013). The deceptively complicated 'elevation ordinary high water mark' and the problem with using it on a Great Lakes shore. *Journal of Great Lakes Research.* 39(2013):527-535.

Norton, RK (2011). Who decides, how and why? Planning for the judicial review of local legislative zoning decisions. *Urban Lawyer.* 43(4):1085-1105.

Norton, RK, LA Meadows, & GA Meadows. (2011). Drawing lines in law books and on sandy beaches: Marking ordinary high water on Michigan's Great Lakes shorelines under the public trust doctrine. *Coastal Management.* 39(2):133-157.

Norton, RK (2008). Using content analysis to evaluate local master plans and zoning codes. *Land Use Policy.* 25(3):432-454.

Norton, RK (2005). Local commitment to state-mandated planning in coastal North Carolina. *Journal of Planning Education and Research.* 25(2):149-171.

Norton, RK (2005). Striking the balance between environment and economy in coastal North Carolina. *Journal of Environmental Planning and Management.* 48(2):177-207.

Norton, RK (2005). More and better planning: State-mandated local planning in coastal North Carolina. *Journal of the American Planning Association*. 71(1):55-71.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
Kings University College, Western University, London, ON	History & Political Science	B.A. 1991 (Honors)
McMaster University, Hamilton, ON	History	M.A. 1992
Western University, London, ON	History	Ph.D 1999

Professional Experience

2014- present	*Director*, University of Michigan Water Center, Graham Sustainability Institute, U Michigan
2012-14	*Deputy Director*, University of Michigan Water Center
2008-14	*Executive Director*, Great Lakes Observing System
2011	*Director (Acting)*, Michigan Sea Grant
2001-10, 2012	*Assistant Director and Research Coordinator*, Michigan Sea Grant
1999-2001	*Research Associate*, Great Lakes Institute for Environmental Research, University of Windsor
1999-2005	*Program Specialist*, Great Lakes Commission, Resource Management and Environmental Quality

Synergistic Activities

Member, US IOOS Advisory Committee	2018 – present
Member, Environmental Information Services Working Group, NOAA Science Advisory Board	2016 – 2019
Member, Advisory Committee, Great Lakes Blue Accounting Initiative, Great Lakes Commission	2015—present
US co-Lead, Data Management and Sharing Task Team, Annex 10, Great Lakes Water Quality Agreement	2013-16
Member, Adaptive Management Task Team, International Joint Commission	2012-2013
US co-Lead, Adaptive Management Work Group, IJC International Upper Great Lakes Study	2009-2012

Key Honors

Michigan Boating Industries Association, Lighthouse Award, for contributions to the Michigan Small Harbors Coalition.	2008
National Association of Conservation Districts – Great Lakes Committee, Recognition of service to the Committee, the Great Lakes Commission and the region to protect and improve soil and water resources.	2005

Key Publications

Policy and Assessment Reports

Rau, E, C Riseng, L Vaccaro, and **J Read.** (2020). "The Dynamic Great Lakes Economy Employment Trends from 2009 to 2018," Michigan Sea Grant College Program, MICHU 20-203.

Scavia, D, S Bocaniov, A Dagnew, Y Hu, B Kerkez, C Long, R Muenich, **J Read**, L Vaccaro, and Y Wang. (2019). *Watershed Assessment of Detroit River Phosphorus Loads to Lake Erie*. Final project report produced by the University of Michigan Water Center. (Available at: myumi.ch/detroit-river).

Brant, C, **J Read,** M Gaden, and R Shaw. (October 2019). "Great Lakes: Lessons from aquatic invasive species cases to inform future invasive species policies and practice." Final project report produced by the University of Michigan Water Center.

Buckner, K, M Doss, M Flanagan, **J Read,** M Shriberg, T Ambs, A Washington, and C Pastoria. (2018). "Assessing the Investment: The economic impact of the Great Lakes Restoration Initiative." Ann Arbor: Great Lakes Commission. (http://bit.ly/GLRIEconomicImpact).

Scavia, D, M Kalcic, R Logsdon Muenich, N Aloysius, C Boles, R Confesor, J DePinto, M Gildow, J Martin, **J Read**, T Redder, S Sowa, Y Wang, and H Yen. (2016). "Informing Lake Erie Agriculture Nutrient Management via Scenario Evaluation." Ann Arbor, MI: University of Michigan Water Center.

Seelbach, PS, **J Read**, KA Buckner, T Eder, and C Manninen. (2014). "Great Lakes Blue Accounting: empowering decisions to realize regional water values." Great Lakes Commission/Council of Great Lakes Governors.

Vaccaro, L and **J Read**. (2011). "Vital to Our Nation's Economy: Great Lakes Jobs, 2011 Report." Michigan Sea Grant College Program, MICHU-11-203, 2011.

Anderson, S, **J Read**, and D Scavia. (2009). "Restoring Great Lakes Ecosystems: Worth the Cost?" Resources for the Future, Weekly Policy Commentary, March 23, 2009. (http://www.rff.org/Publications/WPC/Pages/03_23_09_RestoringGreatLakesEcosystemsWorththeCost.aspx).

Peer-Reviewed

Fischer, J, E Roseman, C Mayer, T Wills, L Vaccaro, **J Read**, B Manny, G Kennedy, R Ellison, R Drouin, R L DeBruyne, A Cotel, J Chiotti, J Boase, and D Bennion. (2021). "A Structured Approach to Remediation Site Assessment: Lessons from 15 Years of Fish Spawning Habitat Creation in the St. Clair-Detroit River System." *Restoration Ecology*. (DOI:10.1111/rec.13359).

Scavia, D, SA Bocaniov, A Dagnew, Y Hu, B Kerkez, CM Long, RL Muenich, **J Read**, L Vaccaro, and Y Wang. (2019). "Detroit River phosphorus loads: Anatomy of a binational watershed." *Journal of Great Lakes Research*. 45(6). (DOI:10.1016/j.jglr.2019.09.008).

Child, M, **J Read,** J Ridal, and M Twiss. (2019). "Symmetry and Solitude: Status and Lessons Learned from Binational Areas of Concern." special issue, *Aquatic Ecosystem Health and Management.* 21(4):478-492. (DOI:10.1080/14634988.2018.1521188).

Trueblood, DD, S Almazán-Casali, J Arnott, M Brass, MC Lemos, K Matso, **J Read**, L Vaccaro, and J Wondolleck. (2019). "Advancing Knowledge for Use in Coastal and Estuarine Management: Competitive Research in the National Estuarine Research Reserve System." *Coastal Management*. (DOI:10.1080/08920753.2019.1598221).

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
Michigan State University, East Lansing	Chemical Engineering	B.S. 2002
University of Michigan, Ann Arbor	Toxicology	Ph.D. 2011
University of Michigan, Ann Arbor	Cancer Biology	Postdoc 2012-2018

Professional Experience

2018-present	Research Assistant Professor, School of Public Health, University of Michigan
2012-2018	Postdoctoral Research Fellow, Department of Pediatrics and Communicable Diseases, Rogel Cancer Center, University of Michigan
2005-2010	Graduate Student Research Assistant, Department of Environmental Health Sciences, University of Michigan
2002-2005	Quality Engineer, Biosynthetic Human Insulin, Eli Lilly and Company, Indianapolis, IN

Synergistic Activities

Ad hoc reviewer, NIEHS Superfund P42 multi project center grants	2021
Member, Environmental Mutagenesis and Genomics Society	2020-present
Primary Instructor for graduate-level course, "Toxicology Case Studies of Environmental Disasters: How Chemicals Cause Harm"	2019-present
Member, Society of Toxicology	2019-present
Secretary-Treasurer, Michigan Chapter of the Society of Toxicology	2019-present

Key Honors

Environmental Mutagenesis and Genomics Society Newly Independent Investigator Engagement Program	2020
Center Scientist Award, University of Michigan Lifestage Environmental Exposures and Disease Center	2018-2019
Hartwell Foundation Postdoctoral Fellowship	2015-2017
American Association for Cancer Research Scholar in Training Award	2015
American Heart Association Predoctoral Fellowship	2009-2010

Key Peer-Reviewed Publications

Liu, S, K Wang, **LK Svoboda**, C Rygiel, K Neier, T Jones, R Cavalcante, J Colacino, D Dolino, and M Sartor. (2021). Perinatal DEHP exposure induces sex- and tissue- specific DNA

methylation changes in both juvenile and adult mice. *Environmental Epigenetics*. (DOI:10.1093/eep/dvab004).

Svoboda, LK, K Wang, TR Jones, JA Colacino, MA Sartor, DC Dolinoy. (2021). Sex-Specific Alterations in Cardiac DNA Methylation in Adult Mice by Perinatal Lead Exposure. *International Journal of Environmental Research and Public Health*. (DOI:10.3390/ijerph18020577).

Jiménez, J, A Apfelbaum, A Hawkins, **LK Svoboda**, A Kumar, R Ocadiz-Ruiz, A Garcia, E Haarer, Z Nwosu, J Badin, T Purohit, D Chen, T Cierpicki, J Grembecka, C Lyssiotis, and ER Lawlor. (2021). EWS-FLI1 and Menin Converge to Regulate ATF4 Activity in Ewing sarcoma. *Molecular Cancer Research*. (DOI:10.1158/1541-7786.MCR-20-0679).

Svoboda, LK, KE Neier, K Wang, RG Cavalcante, CA Rygiel, Z Tsai, TR Jones, S Liu, JM Goodrich, C Lalancette, J Colacino, MA Sartor, and DC Dolinoy. (2020). Tissue and sex-specific programming of DNA methylation by perinatal lead exposure: implications for environmental epigenetics studies. *Epigenetics*. (DOI:10.1080/15592294.2020.1841872).

Neier, K, L Montrose, K Chen, M Malloy, T Jones, **LK Svoboda**, C Harris, P Song, P Subramaniam, M Sartor, and D Dolinoy. (2020). Short- and long-term effects of perinatal phthalate exposures on metabolic pathways in the mouse liver. *Environmental Epigenetics*. (DOI:10.1093/eep/dvaa017).

Svoboda, LK, K Wang, RG Cavalcante, K Neier, JA Colacino, MA Sartor, and DC Dolinoy. (2020). Sex-Specific Programming of Cardiac DNA Methylation by Developmental Phthalate Exposure. *Epigenetics Insights*. 13, (DOI:10.1177/2516865720939971).

Wang, K, S Liu, **LK Svoboda**, C Rygiel, K Neier, TR Jones, JA Colacino, DC Dolinoy, and MA Sartor. (2020). Tissue-and sex-specific DNA methylation changes in mice perinatally exposed to lead. *Frontiers in Genetics*. (DOI:10.3389/fgene.2020.00840).

Malloy, MA, JJ Kochmanski, TR Jones, JA Colacino, JM Goodrich, DC Dolinoy, and **LK Svoboda**. (2019). Perinatal Bisphenol A Exposure and Reprogramming of Imprinted Gene Expression in the Adult Mouse Brain. *Frontiers in Genetics*. 10:951. (DOI:10.3389/fgene.2019.00951).

Perera, BPU, **LK Svoboda**, and DC Dolinoy. (2019). Genomic Tools for Environmental Epigenetics and Implications for Public Health. *Current Opinion in Toxicology*. 18:27–33.

Perera, BPU, C Faulk, **LK Svoboda**, JM Goodrich, and DC Dolinoy. (2019). The Role of Environmental Exposures and the Epigenome in Health and Disease. *Environmental and Molecular Mutagenesis*. (DOI:10.1002/em.22311). Epub ahead of print.

Svoboda, LK, SS Teh, S Kerk, S Sud, A Zebolsky, S Treichel, D Thomas, RA Van Noord, C Halbrook, HJ Lee, D Kremer, L Zhang, B Magnuson, A Bankhead, M Ljungman, E Newman, T Cierpicki, J Grembecka, C Lyssiotis, ER Lawlor. (2018). Menin regulates the serine biosynthetic pathway in Ewing sarcoma. *Journal of Pathology*. 245(3):324-336. PMID: 29672864.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
Carleton U, Ottawa, ON	Ecotoxicology	Postdoc 1998-200
U. Manitoba, Winnipeg, MB	Ecotoxicology	Ph.D. 1998
U. Windsor, Windsor, ON	Biology	M.Sc. 1994
U. Windsor, Windsor, ON	Biology	H.B.Sc. 1991

Professional Experience

2017-Present	Professor and Canada Research Chair Tier I, University of Windsor
2006-2017	Professor and Canada Research Chair Tier II, University of Windsor
2005-2006	Associate Professor, University of Georgia
2002-2005	Assistant Professor, University of Georgia

Synergistic Activities

Board Member, NOAA Great Lakes Observatory System	2018-present
Committee Member, Ocean Tracking Network International Science Advisory Committee	2013-present
Committee Member, IJC Great Lakes Decadal Science Plan	2020-present
Committee Member, GLFC Board of Technical Experts	2014-2020
Evaluation Panel, NSERC Discovery Grants	2016-2019
Editorial Board, *Canadian Journal of Fisheries and Aquatic Science*	2015-2019
President, International Association of Great Lakes Research	2015-2016

Key Honors

PEW Fellow in Marine Conservation	2016-2019
Graduate Student Mentoring Award, University of Windsor	2019

Key Peer-Reviewed Publications

(* Publication of student or post-doctoral fellow under Fisk; 268 lifetime publications, Google Scholar H-Index 69)

Weinz, AA, JK Matley, NV Klinard*, **AT Fisk**, and SF Colborne. (2021). Performance of acoustic telemetry in relation to submerged aquatic vegetation in a nearshore freshwater habitat. *Mar. Freshwater Res.* (DOI:10.1071/MF20245).

*Doherty, CLJ, **AT Fisk**, SJ Cooke, TE Pitcher, and GD Raby*. (2021). Exploring relationships between oxygen consumption and biologger-derived estimates of heart rate in two warmwater piscivores. *Journal of Fish Biology, in press*. (DOI:10.1111/jfb.14923).

Matley, JK*, NV Klinard *, et al., and **AT Fisk**. (2021). Global trends in aquatic animal tracking with acoustic telemetry. *Trends in Ecol. Evol.* (DOI:10.1016/j.tree.2021.09.001).

*Heuvel, C, KG Drouillard, GD Haffner, YM Zhao, **and AT Fisk**. (2021). Influence of feeding ecology on legacy organochlorine contaminants in freshwater fishes of Lake Erie. *Environ. Toxicol. Chem.* (DOI:10.1002/etc.5224).

*****Ivanova, SV, SM Larocque*, **AT Fisk**, and TB Johnson. (2021). Spatio-temporal interactions of native and introduced salmonid top predators in a large lake: Implications for species restoration. *Can. J. Fisheries Aq. Sci*. 78(8):1158-1167.

*Larocque, SM, TB Johnson, and **AT Fisk**. (2021). Trophic niche overlap and abundance reveal potential impact of interspecific interactions on a reintroduced fish. *Can. J. Fisheries Aq. Sci*. 78(6):765-774.

Weinz, AW, JK Matley, NV Klinard*, **AT Fisk,** and SF Colborne. (2020). Identification of predation events in wild fish using novel acoustic transmitters. *Anim. Biotel.* 8:28.

Klinard, NV, JK Matley, SV Ivanova*, SM Larocque*, **AT Fisk**, and TB Johnson. (2020). Application of machine learning to identify predators of stocked fish in Lake Ontario: using acoustic telemetry predation tags to inform management. *J. Fish Bio*. 98(1):237-250. (DOI:10.1111/jfb.14574).

*****Ivanova, SV, TB Johnson, B Metcalfe, and **AT Fisk.** (2020). Spatial distribution of lake trout (*Salvelinus namaycush*) across seasonal thermal cycles in a large lake. *Freshwater Biol.* (DOI:10.1111/fwb.13665).

Matley, JK, MD Faust, GD Raby, Y Zhao, J Robinson, T MacDougall, TA Hayden, **AT Fisk**, Aaron, CS Vandergoot, and CC Krueger. (2020). Seasonal habitat-use differences among Lake Erie's walleye stocks. *J. Great Lakes Res*. 46(3):609-621.

Nawrocki, B, AM McLeod, NE Hussey, SF Colborne*, J Del Papa*, and **AT Fisk**. (2020). Assessing trophic position quantification methods for three piscivorous freshwater fish using stable isotopes and stomach contents. *J. Great Lakes Res.* 46(3):578-588.

*Klinard, NV, JK Matley[*], EA Halfyard, M Connerton, TB Johnson, and **AT Fisk**. (2020). Post-stocking movement and survival of hatchery-reared bloater (*Coregonus hoyi*) reintroduced to Lake Ontario. *Freshwater Bio.* 65(6):1073-1085. (DOI:10.1111/fwb.13491).

*Larocque, SM, TB Johnson, and **AT Fisk**. (2020). Survival and migration patterns of wild- and hatchery-reared Atlantic salmon (*Salmo salar*) smolts in a Lake Ontario tributary using acoustic telemetry. *Freshwater Bio.* 65(5):835-848.

Klinard, NV, EA Halfyard, JK Matley, **AT Fisk,** and TB Johnson. (2019). The influence of dynamic environmental interactions on detection efficiency of acoustic transmitters in a large, deep, freshwater lake. *Anim. Biotel.* 7:17.

Raby, GD, TB Johnson, ST Kessel, TJ Stewart, and **AT Fisk.** (2019). Pop-off data storage tags reveal niche partitioning between native and non-native predators in a novel ecosystem. *J. Appl. Ecol.* 57(1):181-191.

*Heuvel, CE, GD Haffner, YM Zhao, *SC Colborne, *A Despenic, and **AT Fisk**. (2019). The influence of body size and season on the feeding ecology of three freshwater fishes with different diets in Lake Erie. *J. Great Lakes Res*. 45:795-804.

Colborne, SF, TJ Maguire, B Mayer, M Nightingale, GE Enns, **AT Fisk**, KG Drouillard, MN Mohamed, CG Weisener, C Wellen, and SOC Mundle. (2019). Water and sediment as sources of phosphate in aquatic ecosystems: The Detroit River and its role in the Laurentian Great Lakes. *Sci. Total Environ*. 647:1594-1603.

Mumby, JA, SM Larocque, TB Johnson, TJ Stewart, JD Fitzsimons, BC Weidel, MG Walsh, JR Lantry, MJ Yuille, and **AT Fisk**. (2018). Diet and trophic niche space and overlap of Lake Ontario salmonid species using stable isotopes and stomach contents. *J. Great Lakes Res.* 44(6):1383-1392.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
University of Illinois; Urbana, IL	Biology	B.S. 1992 (Honors)
University of Georgia; Athens, GA	Entomology	M.S. 1995
University of Georgia; Athens, GA	Ecology	Ph.D. 2000
University of Maryland; College Park, MD	Biology	Post Doc 2000-2001

Professional Experience

2021- present	University of Wisconsin-Milwaukee	Vice Dean
2014- present	University of Wisconsin-Milwaukee	Professor
2012-present	University of Wisconsin-Milwaukee	Director, Great Lakes Genomics Center
2011-2014	University of Wisconsin-Milwaukee	Shaw Associate Professor
2003-2010	University of Wisconsin-Milwaukee	Shaw Assistant Scientist
2001-2003	EPA NCEA, Policy Fellow	
2000-2001	University of Maryland, Faculty Research Associate	
2000	University of Georgia, Instructor	

Synergistic Activities

Chair, Environmental Nanotechnology Gordon Research Conference, Newry, Maine. 2019

Fulbright U.S. Scholar Award to University of Birmingham, United Kingdom. 2017-2018
For this award I collaborated with U.K. scientists to expand our work on the interaction of nanomaterials with key life processes using metabolomics to identify critical molecules of interaction.

Associate Editor Royal Society of Chemistry Journal, Environmental Science Nano. 2019-present

Editor of the Society of Environmental Toxicology and Chemistry journal Environmental Toxicology and Chemistry. 2015-2019

Environmental Protection Agency, Board of Scientific Counselors, Chemical Safety for Sustainability/Human Health Risk Assessment Subcommittee. 2014-2017

Key Honors

Fellow of the Royal Society of Chemistry 2021

Appointed Associate Editor Royal Society of Chemistry journal *Environmental Science Nano* 2019

Chair (elected) Environmental Nanotechnology Gordon Research Conference 2019

Fulbright U.S. Scholar Award to University of Birmingham, United Kingdom 2017

Elected as an Editor of the Society of Environmental Toxicology and Chemistry journal *Environmental Toxicology and Chemistry*	2015
Nominated by the National Science Foundation to serve on the US EPA FIFRA Scientific Advisory Panel	2015
Inspiring Women in STEM Award from Insight into Diversity	2015
Elected co-chair of the Environmental Nano Gordon Research Conference	2015
Appointed to the U.S. Environmental Protection Agency Board of Scientific Counselors, Chemical Safety for Sustainability/Human Health Risk Assessment Subcommittee	2014
Environmental Science & Technology Excellence in Review Award	2014
Elected to the Editorial Board *Environmental Toxicology and Chemistry*	2013
UWM Graduate School Excellence in Research Award	2011
National Academies of Science Panel to Evaluate the Research Strategy for the Environmental Health and Safety of Nanomaterials	2009-2013
Forty Under 40 Award, Milwaukee Magazine	2008
Greater Milwaukee Foundation, Shaw Scientist Endowment	2003
American Association for the Advancement of Science Science and Technology Policy Fellowship	2001

Key Peer-Reviewed Publications

Zhi, H, AL Mianecki, DW Kolpin, **RD Klaper,** LR Iwanowicz, GH & LeFevre. (2021).Tandem field and laboratory approaches to quantify attenuation mechanisms of pharmaceutical and pharmaceutical transformation products in a wastewater effluent-dominated stream. *Water Research*. 203:117537.

Niemuth, NJ, BJ Curtis, ED Laudadio, E Sostare, EA Bennett, NJ Neureuther, NJ, ... and **RD Klaper.** (2021). Energy Starvation in Daphnia magna from Exposure to a Lithium Cobalt Oxide Nanomaterial. *Chemical Research in Toxicology*. 34(11):2287-2297.

Webb, DT, H Zhi, DW Kolpin, **RD Klaper**, LR Iwanowicz, and GH LeFevre. (2021). Emerging investigator series: municipal wastewater as a year-round point source of neonicotinoid insecticides that persist in an effluent-dominated stream. *Environmental Science: Processes & Impacts.* 23(5):678-688.

Schulz, K, MR Silva, and **RD Klaper.** (2020). Distribution and effects of branched versus linear isomers of PFOA, PFOS, and PFHxS: A review of recent literature. *Science of the Total Environment.* 733:139186.

Zhi, H, DW Kolpin, **RD Klaper**, LR Iwanowicz, SM Meppelink, and GH LeFevre. (2020). Occurrence and spatiotemporal dynamics of pharmaceuticals in a temperate-region wastewater effluent-dominated stream: variable inputs and differential attenuation yield evolving complex exposure mixtures. *Environmental Science & Technology*. 54(20):12967-12978.

Niemuth, NJ, Y Zhang, AA Mohaimani, A Schmoldt, ED Laudadio, RJ Hamers, and **RD Klaper.** (2020). Protein Fe–S Centers as a Molecular Target of Toxicity of a Complex Transition Metal Oxide Nanomaterial with Downstream Impacts on Metabolism and Growth. *Environmental Science & Technology*. 54(23):15257-15266.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
Andhra University, Waltair, India	Mechanical Engineering	B.S. 1984
Indian Institute of Sci, Bangalore, India	Mechanical Engineering	Ph.D. 1990
C-MMACS (Center for Math Modeling & Computer Simulation, Bangalore, India)	Earth, Ocean and Atmospheric Sciences	Postdoc 1990-1993

Professional Experience

2014 – Present:	Professor, Civil & Environmental Engineering, Michigan State University
2017 – 2019	Associate Chair for Graduate Studies, Civil & Environmental Engineering, Michigan State University
2017 – 2017	Distinguished Visiting Fellow, The Institute of Advanced Studies, University of Birmingham, Edgbaston 2TT B15, UK (Mar – July 2017)
2007 – 2014	Associate Professor, Civil & Environmental Engineering, Michigan State University
2002 – 2007	Assistant Professor, Civil & Environmental Engineering, Michigan State University
1998 – 2002	Visiting Assistant Professor, Michigan State University
1993 – 1997	Scientist, C-MMACS (Center for Math Modeling & Computer Simulation, Bangalore, India)

Synergistic Activities

Convener, Special Session "H22F - Understanding Biogeochemical and Hydrological Processes in the Laurentian Great Lakes Basin Across Scales" American Geophysical Union, Fall Meeting (with Alicia Sendrowski and Yadu Pokhrel)	December 2021
Convener, Special Session "H53C - Agriculture/Crop Yield and Natural Ecosystems Productivity Forecast for Building Resilience and Climate Adaptability Using Modeling and Remote Sensing", American Geophysical Union, Fall Meeting (with N. Das, K. Andreadis and H. Geli)	December 2021
Guest Editor, Special Issue "Advances in Integrating Distributed Hydrologic Models with Novel Monitoring Data", Journal of *Water*	2017
Converner, Special Session "Recent Advances in Understanding the Hydrology of the Great Lakes Region", American Geophysical Union, Fall Meeting, San Francisco, CA (Co-chair: B. Lofgren, A.D. Gronewold, GLERL), Session # H54E and H54I.	December 3-7, 2012

Key Honors

Elected Fellow, Geological Society of America (GSA)	2013
Lilly Teaching Fellow, Michigan State University	2004
Outstanding Remediation Project Award, National Groundwater Association, Ohio	2002
Professor C.V. Raman Young Scientist Award for "…*Outstanding Contributions to Computational Sciences and Earth Sciences*", Government of India	1996

Key Peer-Reviewed Publications

Safaie, A, CJ Weiskerger, MB Nevers, MN Byappanahalli, and **MS Phanikumar**. (2021). Evaluating the impacts of foreshore sand and birds on microbiological contamination at a freshwater beach. *Water Research*. Vol. 190. 116671, pp. 1-13.

Safaie, A, CJ Weiskerger, TD Nguyen, B Acrey, RG Zepp, M Molina, M Cyterski, G Whelan, YA Pachepsky, and **MS Phanikumar**. (2020). Modeling the photoinactivation and transport of somatic and F-specific coliphages at a Great Lakes beach. *J. Environmental Quality*. 49(6):1612-1623.

Nevers, MB, MN Byappanahalli, CH Nakatsu, JL Kinzelman, **MS Phanikumar**, DA Shively, and AM Spoljaric. (2020). Interaction of bacterial communities and indicators of water quality in shoreline sand, sediment, and water of Lake Michigan. *Water Research*. Article: 115671, Vol. 178.

Weiskerger, CJ, J Brandão, W Ahmed, A Aslan, L Avolio, BD Badgley, AB Boehm, TA Edge, JM Fleisher, CD Heaney, L Jordao, JL Kinzelman, JS Klaus, GT Kleinheinz, P Meriläinen, JP Nshimyimana, **MS Phanikumar**, AM Piggot, T Pitkänen, C Robinson, MJ Sadowsky, C Staley, ZR Staley, EM Symonds, LJ Vogel, KM Yamahara, RL Whitman, HM Solo-Gabriele, and VJ Harwood. (2019). Impacts of a changing earth on microbial dynamics and human health risks in the continuum between beach water and sand. *Water Research*. 162:456-470.

Nevers, MB, MN Byappanahalli, D Shively, PM Buszka, PR Jackson, and **MS Phanikumar**. (2018). Identifying and eliminating sources of recreational water quality degradation along an urban coast. *J. Environmental Quality*. 47(5):1042-1050.

Zhang, J, H Qiu, X Li, J Niu, MB Nevers, X Hu, and **MS Phanikumar.** (2018). Real-time nowcasting of microbiological water quality at recreational beaches: A wavelet and artificial neural network-based hybrid modeling approach. *Environmental Science & Technology*. 52:8446-8455.

Safaie, A, A Wendzel, Z Ge, MB Nevers, RL Whitman, SR Corsi, and **MS Phanikumar**. (2016). Comparative evaluation of statistical and mechanistic models of *Escherichia coli* at beaches in southern Lake Michigan. *Environmental Science & Technology*. 50:2442-2449.

Thupaki, P, **MS Phanikumar**, DJ Schwab, MB Nevers, and RL Whitman. (2013). Evaluating the role of sediment-bacteria interactions on *Escherichia coli* concentrations at beaches in southern Lake Michigan. *J. Geophys. Res. Oceans*. Vol. 118.

Ge, Z, RL Whitman, MB Nevers, **MS Phanikumar,** and MN Byappanahalli. (2012). Nearshore hydrodynamics as loading and forcing factors for *Escherichia coli* contamination at an embayed beach. *Limnology and Oceanography*. 57(1):362-381. (DOI:10.4319 / lo.2012.57.1.0362).

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
University of Minnesota-Duluth	Biology	B.S. 1996
University of Notre Dame	Biology (Aquatic Ecology)	M.S. 2000
University of Notre Dame	Biology (Aquatic Ecology)	Ph.D. 2004

Professional Experience

2018 – present	Director, Center for Freshwater Research and Education & Professor, School of Natural Resources and Environment, Lake Superior State University
2014 – 2018	Professor & Co-Director of the Aquatic Research Laboratory, Lake Superior State University
2015	Visiting Scientist, Center for Limnology, UW-Madison (spring semester)
2008 – 2014	Associate Professor & Co-Director of the Aquatic Research Laboratory, Lake Superior State University
2004 – 2008	Assistant Professor & Co-Director of the Aquatic Research Laboratory, Lake Superior State University
2001 – 2004	Life Scientist, U.S. Environmental Protection Agency, Region 5
2000 – 2004	Graduate Research Fellow, Department of Biological Sciences, University of Notre Dame

Synergistic Activities

President, Society for Freshwater Science	2021-present
Advisor, Lake Superior Committee, Great Lakes Fishery Commission	2016-present
Advisor, LSSU Fisheries and Wildlife Club (AFS Student Sub-unit)	2006-2021
Governor-Appointee, Michigan Environmental Sciences Advisory Board	2018-present
Director of host site for US Coast Guard Center of Expertise	2021-present

Key Honors

President-elect, Society for Freshwater Science	2020
Justin Leonard Award of Excellence, MI American Fisheries Society	2020
State of Michigan Distinguished Professor of the Year	2014
LSSU Distinguished Professor of the Year	2012
LSSU Excellence in Academic Advising Award	2011

Key Peer-Reviewed Publications (*undergraduate student)

Molina-Moctezuma, A, N Godby, KL, Kapuscinski, EF Roseman, K Skubik*, and **A Moerke**. (2021). Response of fish assemblages to restoration or rapids habitat in a Great Lakes connecting channel. *Journal of Great Lakes Research.* 47(4):1182-1191.

Bosio, SF, PD Shirey, SA Entrekin, TJ Hoellein, **AH Moerke**, EJ Rosi, JL Tank, and GA Lamberti. (2021). Dynamics of large wood added to midwestern USA streams. *River Research and Applications.* 37(6):843-857.

Molina-Moctezuma, A, E Ellis, KL Kapuscinski, EF Roseman, T Heatlie, and **A Moerke**. (2021). Restoration of rapids habitat in a Great Lakes connecting channel, the St. Marys River, Michigan. *Restoration Ecology.* 29(1): e13310.

Gerig, B, DT Chaloner, S Cullen, R Greil, KL Kapuscinski, **A Moerke**, and GA Lamberti. (2019). Trophic ecology of salmonine predators in Northern Lake Huron with emphasis on Atlantic salmon (Salmo salar). *Journal of Great Lakes Research.* 45:160-166.

Kovalenko, K, L Johnson, V Brady, J Ciborowski, M Cooper, J Gathman, G Lamberti, **A Moerke**, C Ruetz, and D Uzarski. (2019). Hot spots and bright spots in functional and taxonomic diversity. *Freshwater Science*. (DOI:10.1086/704713).

Tiegs, S and 152 authors including **A Moerke**. (2019). Global patterns and drivers of ecosystem functioning in rivers and riparian zones. *Science Advances.* 5:eaav0486.

Uzarski, DG, DA Wilcox, VJ Brady, MJ Cooper, DA Albert, JJH Ciborowski, NP Danz, A Garwood, JP Gathman, TM Gehring, GP Grabas, RW Howe, LB Johnson, GA Lamberti, **AH Moerke**, GJ Niemi, T Redder, CR Ruetz III, AD Steinman, DC Tozer, TK O'Donnell. (2019). Leveraging landscape-level monitoring and assessment program for developing resilient shorelines throughout the Laurentian Great Lakes. *Wetlands.* (DOI:10.1007/s13157-019-01139-w).

Cooper, MJ, GA Lamberti, **AH Moerke**, CR Ruetz III, DA Wilcox, VJ Brady, TN Brown, JH Ciborowski, JP Gatham, GP Grabas, LB Johnson, and DG Uzarski. (2018). An expanded fish-based index of biotic integrity for Great Lakes coastal wetlands. *Environmental Monitoring and Assessment.* (DOI:10.1007/s10661-018-6950-6).

Moerke, A, C Ruetz III, T Simon, and C Pringle. (2017). Chapter 19: Macroconsumer-resource interactions. Pages 399-412 *in* R. Hauer and G. Lamberti, editors. Methods in Stream Ecology, 3rd edition, Academic Press, CA.

Uzarski, DG, VJ Brady, MJ Cooper, DA Wilcox, DA Albert, RP Axler, P Bostwick, T Brown, JH Ciborowski, NP Danz, JP Gathman, TM Gehring, GP Grabas, A Garwood, RW Howe, LB Johnson, GA Lamberti, **AH Moerke**, BA Murry, GJ Niemi, CJ Norment, CR Ruetz III, AD Steinman, D Tozer, R Wheeler, TK O'Donnell, and JP Schneider. (2016). Standardized measures of coastal wetland condition: Implementation at a Laurentian Great Lakes Basin-wide scale. *Wetlands.* 37(1):15-32. (DOI:10.1007/s13157-016-0835-7).

Gerig, B, D Chaloner, D Janetski, R Rediske, J O'Keefe, **A Moerke**, and G Lamberti. (2016). Congener patterns of persistent organic pollutants reveal Pacific salmon contaminant delivery to Great Lakes tributaries. *Environmental Science & Technology.* 50(2): 554-563.

Gerig, B*, **A Moerke**, R Greil, and S Koproski. (2011). Movement patterns and habitat characteristics of lake sturgeon (Acipenser fulvescens) in the St. Marys River. *Journal of Great Lakes Research.* 37(Suppl. 2):54-60.

Turschak, B*, **A Moerke**, and B Evans. (2011). Spatial and seasonal changes in the zooplankton community of the St. Marys River. *Journal of Great Lakes Research.* 37(Suppl. 2):21-27.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
U. Wisconsin Madison	Zoology	B.Sc. 1978
U. Wisconsin Madison	Zoology	M.Sc. 1983
U. Stockholm, Sweden	Zoology	Ph.D. 1988

Professional Experience

2009-present	Director, Cornell Biological Field Station
2009-present	Professor, Department of Natural Resources, Cornell University
2001-2009	Associate Professor, Department of Natural Resources, Cornell University
1992-2001	Senior Research Associate, Department of Natural Resources, Cornell University

Synergistic Activities

Leader: EPAs Great Lakes biomonitoring program (chl-a, zooplankton, mysids, benthos). NY DEC/USGS biomonitoring program in Lake Ontario (chl-a, TP, zooplankton), NYSDEC Warmwater fisheries research program, EPA genetic barcoding project.

Associated Editor: J. Great Lakes Res.	2009-present
Aquat. Ecosyst. Health Manage.	2011- present
Editor of books and special issues last decade: Status of Lake Ontario AEHM.	2012-15
Ecology of fish in inland waters Fish Res (2014-15), CSMI Lake Ontario, JGLR.	2016-17
Oneida Lake, a managed ecosystem – AFS Publications.	2016
GLNPO Biomonitoring program, JGLR.	2017-18
Lake Baikal, JGLR.	2018-20
Fundamental theories and concepts – Encyclopedia of Inland Waters.	2019-22

Council of Fellows: Cooperative Institute for Great Lakes Research.
Leader of acoustic GLFC
Fisheries acoustic working group, author of fisheries acoustics chapter for Fisheri Techniques, chapter on standard fisheries ampling in Great Lakes fisheries, chapter on percid sampling in NYSDEC sampling manual.

Key Honors

Chandler-Misener Award for most notable paper-Journal of Great Lakes Res.	2018
Robert E Kendall Award for best paper in Trans of American Fisheries Society.	2017
Best student authored paper in J Great Lakes Research.	2016

Key Peer-Reviewed Publications

Ogorelec, Ž, **LG Rudstam**, and D Straile. (2022). Can young-of-the-year invasive fish keep up with young-of-the-year native fish? A comparison of feeding rates between invasive sticklebacks and whitefish. *Ecol. Evol.* 12:e8486. (DOI:10.1002/ece3.8486).

Sharma, S, DC Richardson, RI Woolway, MA Imrit, D Bouffard, K Blagrave, J Daly, A Filazzola, N Granin, J Korhonen, J Magnuson, W Marszelewski, SIS. Matsuzaki, W Perry, DM Robertson, **LG Rudstam**, GA Weyhenmeyer, and H Yao. (2021). Loss of ice cover, shifting phenology, and more extreme events in Northern Hemisphere lakes. *JGR Biogeosciences.* 126, e2021JG006348.

Kakouei, K, B Kraemer, O Anneville, L Carvalho, H Feuchtmayr, J Graham, S Higgins, F Pomati, **LG Rudstam**, J Stockwell, S Thackeray, M Vanni, and R Adrian. (2021). Phytoplankton and cyanobacteria abundances in mid-21st century lakes depend strongly on future land use and climate projections. *Global Change Biology*. 27:6409-6422.

Burlakova, LE, AY Karatayev, AR Hrycik, SE Daniel, K Mehler, **LG Rudstam**, JM Watkins, R Dermott, J Scharold, A Elgin, T Nalepa, S. Lozano, and EK Hinchey. (2021). Density data for benthic invertebrate assemblages of Lake Ontario from 1964 to 2018. *Ecology in press.*

Reinl, KL, JD Brookes, CC Carey, TD Harris, BW Ibelings, AM Morales-Williams, LN de Senerpont-Domis, KS Atkins, PD F Isles, MR Kelly, JP Mesman, RL North, **LG Rudstam**, RL Smyth, JAA Stelzer, JJ Venkiteswaran, K Yokota, and Q Zhan. (2021). Cyanobacterial blooms in oligotrophic lakes: Shifting the high nutrient paradigm. *Freshw. Biol.* 66:1846-1849. (DOI:10.1111/fwb.13791).

Evans, TM, ZS Feiner, **LG Rudstam**, DM Mason, JM Watkins, ED Reavie, AE Scofield, LE Burlakova, AY Karatayev, and WG Sprules. (2021). Size spectra analysis in the Laurentian Great Lakes: analysis of lake and season effects across a decade. *Can. J. Fish. Aquat. Sci*. In press.

Bunnell, DB, SA Ludsin, RL Knight, **LG Rudstam**, CE Williamson, TO Höök, PD Collingsworth, BM Lesht, RP Barbiero, AE Scofield, ES Rutherford, L Gaynor, HA Vanderploeg, and MA Koops. (2021). Consequences of changing water clarity on the fish and fisheries of the Laurentian Great Lakes. *Can J. Fish. Aquat. Sci.* In press.

Doubek, JP, O Anneville, G Dur, AM Lewandowska, VP Patil, JA Rusak, N Salmaso, CT Seltmann, D Straile, P Urrutia-Cordero, P Venail, R Adrian, MB Alfonso, CL DeGasperi, E d Eyto, H Feuchtmayr, EE Gaiser, SF Girdner, JL Graham, HP Grossart, J Hejzlar, S Jacquet, G Kirillin, ME Llames, SIS Matsuzaki, ER Nodine, MC Piccolo, DC Pierson, A. Rimmer, **LG Rudstam**, S Sadro, HM Swain, SJ Thackeray, W Thiery, P Verburg, T Zohary, JD Stockwell. (2021). The extent and variability of storm-induced temperature changes in lakes measured with long-term and high-frequency data. *Limn Oceanogr*. 66:1979-1992. (DOI:10.1002/lno.11739).

Burlakova, LE, AY Karatayev, AR Hrycik, SE Daniel, K Mehler, **LG Rudstam**, JM Watkins, Dermott, J Scharold, A Elgin, T Nalepa, and EK Hinchey. (2021). Six decades of Lake Ontario: ecological history according to benthos. *J. Great Lakes Res*. 47: on line.

Karatayev, AY, LE Burlakova, K Mehler, AK Elgin, **LG Rudstam**, JM Watkins, and M Wick. (2022). Dreissena in Lake Ontario 30 years post-invasion. *J. Great Lakes Res.* 47: in press.

Holda, TJ, **LG Rudstam**, SA Pothoven, DM Warner, DS Khrystenko, and DM Watkins. (2021). Lake-wide, annual status in Mysis diluviana in Lake Michigan in 2015. *J. Great Lakes Res.* 47:190-203.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
University of Vermont	Botany	B.S. 1979 (cum laude; Phi Beta Kappa)
U. of Rhode Island	Botany	M.S. 1983
Oregon State Univ.	Botany	Ph.D. 1987
Oak Ridge National Labs	Ecosystem Science	Postdoc 1987-1990

Professional Experience

2001-present	Director, Annis Water Resources Institute, Grand Valley State University
1996-2001	Director, Lake Okeechobee Division, South Florida Water Management District
1993-1996	Supervising Environmental Scientist, Lake Okeechobee Division, South Florida Water Management District
1992-1993	Senior Scientist, Science Applications International Corp.
1990-1992	Research Scientist, Oak Ridge National Laboratory

Synergistic Activities

Member, US EPA Great Lakes Advisory Board	2020-present
Member, National Academy of Sciences Committee on Independent Science Review of Everglades Restoration Progress	2021- present
University of Michigan's Water Center Advisory Board	2015-present
NOAA NERRS (National Estuarine Research Reserve System) Science Collaborative Advisory Board	2014-present
Member, Work Group for IJC Phase II Early Warning System	2020-present
Member, Science/Technical Advisory Boards for Central Michigan University's Biostation, Healing our Waters, Muskegon Lake Watershed Partnership	present

Key Honors

Fellow, Society of Freshwater Science	2021
Award of Excellence, National Garden Clubs, Inc.	2017
Keiser Distinguished Lecturer in Life Sciences, Ohio Northern University	2016
Patricia B. Johnson Award for Leadership and Innovative Grantmaking, Community Foundation for Muskegon County	2016
Paul Harris Fellow, Rotary Foundation of Rotary International	2011
Massapequa (NY) High School Hall of Fame	2009
Joan Hodges Queneau Palladium Medal (as part of the Restudy Team) for restoration of the Everglades, National Audubon Society	2000
Research Award for Foreign Specialists, the National Institute of	1997

Agro-Environmental Sciences (NIAES), Tsukuba, Japan
Best Student Paper: Northeast Algal Symposium. Woods Hole, MA. 1983
Phi Beta Kappa: University of Vermont 1979

Key Peer-Reviewed Publications

Steinman, AD and B Spears (Editors). (2020). Internal Phosphorus Loading: Causes, Case Studies, and Management. Publisher: J. Ross Publishing, Boca Raton, FL. 466 pp.

Steinman, AD, Scott, J, Green, L, Partridge, C, Oudsema, M, Hassett, M Kindervater, E, and R Rediske. (2020). Persistent Organic Pollutants, Metals, and the Bacterial Community Composition Associated with Microplastics in Muskegon Lake (MI). *Journal of Great Lakes Research*. 46:1444-1458.

Sterner, RW, P Ostrom, NE Ostrom, JV Klump, **AD Steinman**, EA Dreelin, MJ Vander Zanden, and A Fisk. (2017). Grand challenges for research in the Laurentian Great Lakes. *Limnology & Oceanography*. 62:2510-2523.

Steinman, AD, BJ Cardinale, WR Munns, ME Ogdahl, et al. (2017). Ecosystem services in the Great Lakes. *Journal of Great Lakes Research.* 43:161-168.

Steinman, AD, GA Lamberti, P Leavitt, and DG Uzarski. (2017). Biomass and pigments of benthic algae. Pages 223-241. *In: Methods in Stream Ecology.* Vol 1 (3rd Ed.) R. Hauer and G. Lamberti (editors). Elsevier Press.

Duhamel, S, G Nogaro, and **AD Steinman.** (2016). Effects of water level fluctuation and sediment–water nutrient exchange on phosphorus biogeochemistry in two Great Lakes coastal wetlands. *Aquatic Sciences*. 79:57-72.

Smith, SDP, PB McIntyre, BS Halpern, RM Cooke, AL Marino, GL Boyer, A Buchsbaum, GA Burton Jr., LM Campbell, WL Chadderton, JJH Ciborowski1, PJ Doran, T Eder, DM Infante, LB Johnson, JG Read, JB Rose, ES Rutherford, SP Sowa, **AD Steinman**, and JD Allan. (2015). Rating impacts in a multi-stressor world: a quantitative assessment of 50 stressors affecting the Great Lakes. *Ecological Applications.* 25:717-728.

JD Allan, PB McIntyre, SDP Smith, BS Halpern, G Boyer, A Buchsbaum, A Burton, L Campbell, L Chadderton, J Ciborowski, P Doran, T Eder, DM Infante, LB Johnson, CG Joseph, AL Marino, A Prusevich, J Read, J Rose, E Rutherford, S Sowa, and **AD Steinman.** (2013). Joint analysis of stressors and ecosystems services to enhance restoration effectiveness. *Proceedings of the National Academy of Sciences*. 110(1):372-377. (DOI:10.1073/pnas.1213841110).

Cooper, MJ, **AD Steinman**, and DG Uzarski. (2013). Influence of geomorphic setting on the metabolism of Lake Huron fringing wetlands. *Limnology & Oceanography*. 58:452-464.

Larsen, JH, A Trebitz, **AD Steinman**, MJ Wiley, M Carlson-Mazur, V Pebbles, H Braun, and P Seelbach. (2013). Great Lakes rivermouth ecosystems: scientific synthesis and management implications. *Journal of Great Lakes Research.* 39:513-524.

Ogdahl, M, VL Lougheed, RJ Stevenson, and **AD Steinman**. (2010). Influences of multi-scale habitat on metabolism in a coastal Great Lakes watershed. *Ecosystems*. 11:222-238.

Baron, JS, NL Poff, PL Angermeier, CN Dahm, PH Gleick, NG Hairston, Jr., RB Jackson, CA Johnston, BG Richter, and **AD Steinman**. (2002). Meeting ecological and societal needs for freshwater. *Ecological Applications.* 12:1447-1460.

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Director, Large Lakes Observatory and Professor, Biology
University of Minnesota Duluth, Duluth, MN 55812
(218) 726-7926, stern007@d.umn.edu

Education

Institution(s) & Location	Major/Area	Degree & Year(s)
University of Illinois, Champaign, IL	Biology	B.S. 1980
U. of Minnesota, Minneapolis, MN	Ecology, Evolution & Behavior	Ph.D., 1986

Professional Experience

2014–present	Director, Large Lakes Observatory, University of Minnesota Duluth
2014–present	Professor, Biology, University of Minnesota Duluth
2007–9	Director, Division Environmental Biology, National Science Foundation, Wash DC
1998–2003	Head, Dept. Ecology, Evolution and Behavior, University of Minnesota Twin Cities
1994 –2014	Associate/Full Professor, University of Minnesota Twin Cities
1988–1994	Assistant/Associate Professor, University of Texas at Arlington
1986–87	Max Planck Fellow then NSF/NATO Postdoctoral Fellow, Max Planck Institute fuer Limnologie, Ploen, West Germany

Synergistic Activities

Director of the Division of Environmental Biology at NSF 2007-9
President-Elect, Northeastern Association of Marine and Great Lakes Laboratories
Newly appointed member of the Scientific Advisory Board, International Joint Commission
Member of University of Minnesota's Water Council (water.umn.edu), 2017-present
which coordinates and serves as a bridge to the external community on many topics in water scholarship
Lead author for Grand Challenges report for the Great Lakes

Key Honors

Recipient of the John Martin Award from the Association for the Sciences of Limnology and Oceanography 2017
Appointed Resident Fellow, Institute on the Environment, University of Minnesota 2013
Awarded the Journal of Great Lakes Research Highly Cited Paper Award of 2012 for Sterner, R.W. 2010 In situ-measured primary production in Lake Superior. JGLR 36: 139-149 2012
Named as Kilham lecturer, International Society of Limnology (formerly SIL) 2010

Key Peer-Reviewed Publications

Sterner, RW (2021). The Laurentian Great Lakes: A biogeochemical test bed. *Annual Review of Earth and Planetary Sciences*. 49:201–229.

Sterner, RW, KL Reinl, BM Lafrancois, S Brovold, and TR Miller. (2020). A first assessment of cyanobacterial blooms in oligotrophic Lake Superior. *Limnology and Oceanography*. 65:2984–2998.

Sterner, RW, B Keeler, S Polasky, R Poudel, K Rhude, and M Rogers. (2020). Ecosystem services of Earth's largest freshwater lakes. *Ecosystem Services*. 41:101046.

Cooney, E M, P McKinney, **RW Sterner,** GE Small, and EC Minor. (2018). Tale of two storms: Impact of extreme rain events on the biogeochemistry of Lake Superior. *Journal of Geophysical Research: Biogeosciences*. 123:1719-1731. (DOI:10.1029/2017JG004216).

Rozmarynowycz, MJ, BFN Beall, GS Bullerjahn, GE Small, **RW Sterner**, SS Brovold, NA D'souza, SB Watson, and RML McKay. (2019). Transitions in microbial communities along a 1600 km freshwater trophic gradient. *Journal of Great Lakes Research*. 45:263–276. (DOI:10.1016/j.jglr.2019.01.004).

Sterner, RW, P Ostrom, NE Ostrom, JV Klump, AD Steinman, EA Dreelin, MJ vander Zanden, and AT Fisk. (2017). Grand challenges for research in the Laurentian Great Lakes. *Limnology and Oceanography*. 62:2510–2525. (DOI:10.1002/lno.10585).

Hessen, DO, JJ Elser, **RW Sterner**, and J Urabe. (2013). Ecological stoichiometry: An elementary approach using basic principles. *Limnology and Oceanography*. 58:2219–2236. (DOI:10.4319/lo.2013.58.6.2219).

Finlay, JC, GE Small, and **RW Sterner. (**2013). Human influences on ecosystem nitrogen removal in lakes. *Science*. 342:247–250. (DOI:10.1126/science.1242575).

Sterner, RW (2011). C:N:P stoichiometry in Lake Superior: freshwater sea as end member. *Inland Waters*. 1:29–46. (DOI:10.5268/IW-1.1.365).

Sterner, RW (2010). In situ-measured primary production in Lake Superior. *Journal of Great Lakes Research.* 36:139–149. (DOI:10.1016/j.jglr.2009.12.007).

Sterner, RW, TM Smutka, RML McKay, Q Xiaoming, ET Brown, and RM Sherrell. (2004). Phosphorus and trace metal limitation of algae and bacteria in Lake Superior. *Limnology and Oceanography*. 49:495–507. (DOI:10.4319/lo.2004.49.2.0495).

Sterner, RW and JJ Elser. (2002). Ecological Stoichiometry: The Biology of Elements from Molecules to the Biosphere. Princeton University Press. ISBN 978-0-691-07491-7.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
Grand Valley State University	Biology	B.S. 1992
Central Michigan University		M.S. 1995
Michigan State University	(Dual) Limnology & EEBB	Ph.D. 1999
Michigan State University	Wetland Ecology	Postdoc 1999-2000

Professional Experience

2007-present	Central Michigan University
2010-present	Director, CMU Institute for Great Lakes Research (IGLR)
2010-present	Director of CMU Biological Station (CMUBS)
2013-present	Professor of Biology
2009-2013	Associate Professor of Biology
2010-2011	Director of Great Lakes and Environmental Research
2007-2009	Assistant Professor of Biology
2007-2009	Director of Great Lakes Research
2000-2007	Grand Valley State University
2002-2007	Assistant Professor of Water Resources
2001-2002	Senior Research Scientist
2000-2002	Adjunct Professor of Biology
1999-2001	Michigan State University
1999-2001	Visiting Assistant Professor

Synergistic Activities

Lead PI Coastal Wetland Monitoring: Continued Implementation. US EPA (5 years). $10,000,000.00	2015-2020
Cooperative Institute for Great Lakes Research (CIGLR) - Council of Fellows.	2017-Present
International Joint Commission Invited Expert. Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee. Canada Centre for Inland Waters, Burlington, Ontario. April 3,4	2017
International Joint Commission Working Group Member – Evaluation of Stressor Interactions in the Great Lakes	2018-2020
State of the Great Lakes Author. US EPA and Environment and Climate Change Canada. Wetlands Indicators	

Key Peer-Reviewed Publications

Jenny, JP, O Anneville, F Arnaud, [et al, including **DG Uzarski**]. (2020). Scientists' Warning to Humanity: Rapid degradation of the world's large lakes. *Journal of Great Lakes Research*. (DOI:10.1016/j.jglr.2020.05.006).

Kneisel, AN, MJ Cooper, AK Monfils, S Haidar, and **DG Uzarski**. (2020). Ecological data as a resource for invasive species management in U.S. Great Lakes coastal wetlands. *Journal of Great Lakes Research*. (DOI:10.1016/j.jglr.2020.01.006).

Gehring, TM, CR Blass, BA Murry, and **DG Uzarski**. (2020). Great Lakes coastal wetlands as suitable habitat for invasive mute swans in Michigan. *Journal of Great Lakes Research*. 46(2):323-329.

Harrison, AM, AJ Reisinger, MJ Cooper, VJ Brady, JJH Ciborowski, KE O'Reilly, CR Ruetz III, DA Wilcox, and **DG Uzarski.** (2019). A basin-wide survey of coastal wetlands of the Laurentian Great Lakes: development and comparison of water quality indices. *Wetlands.* 40:465-477(2020).

Uzarski, **DG,** DA Wilcox, VJ Brady, MJ Cooper, DA Albert, JJH Ciborowski, NP Danz, A Garwood, JP Gathman, TM Gehring, GP Grabas, RW Howe, LB Johnson, GA Lamberti, AH Moerke, GJ Niemi, T Redder, CR Ruetz III, AD Steinman, DC Tozer, and TK O'Donnell. (2019). Leveraging a landscape-level monitoring and assessment program for developing resilient shorelines throughout the Laurentian Great Lakes. *Wetlands*. 39(6):1357-1366.

Hilts, DJ, MW Belitz, TM Gehring, KL Pangle, and **DG Uzarski**. (2019). Climate change and nutria range expansion in the Eastern United States. *The Journal of Wildlife Management*. 83(3):591-598.

Horton, DJ, KR Theis, **DG Uzarski**, and DR Learman. (2019). Microbial community structure and microbial networks correspond to nutrient gradients within coastal wetlands of the Great Lakes. *FEMS Microbiology Letters*. 95(4):fiz033.

Sierszen, ME, LS Schoen, JM Kosiara, JC Hoffman, MJ Cooper, and **DG Uzarski**. (2019). Relative contributions of nearshore and wetland habitats to coastal food webs in the Great Lakes. *Journal of Great Lakes Research*. 45(1):129-137.

Smith, SDP, DB Bunnell, GA Burton Jr., JJH Ciborowski, AD Davidson, CE Dickinson, LA Eaton, PC Esselman, MA Evans, DR Kashian, NF Manning, PB McIntyre, TF Nalepa, A Perez-Fuentetaja, AD Steinman, **DG Uzarski**, and JD Allan. (2019). Evidence for interactions among environmental stressors in the Laurentian Great Lakes. *Ecological Indicators*. 101:203-211.

Horton, DJ, MJ Cooper, AJ Wing, PS Kourtev, **DG Uzarski**, and DR Learman. (2018). Microbial subnetworks related to short-term diel O2 fluxes within geochemically distinct freshwater wetlands. *FEMS Microbiology Letters*. 365(24):fny26.

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Education

Institution(s) & Location	Major/Area	Degree & Year(s)
Ohio University	Environmental Sciences	B.S. 1997
Bowling Green State University	Biological Sciences	M.S. 2002
Bowling Green State University	Biological Sciences	Ph.D. 2009

Professional Experience

2017-present	Director, Ohio Sea Grant College Program and OSU's Stone Laboratory (*Employer*: The Ohio State University
2016-2017	Interim Director, Ohio Sea Grant College Program and OSU's Stone Laboratory
2014-2016	Associate Director, Ohio Sea Grant College Program and OSU's Stone Laboratory
2011-2014	Assistant Director, Ohio Sea Grant College Program and OSU's Stone Laboratory
2007-2015	Instructor, The Ohio State University's F. T. Stone Laboratory
2009-2011	Assistant Professor, Kutztown University of Pennsylvania
2002-2009	Instructor, Bowling Green State University

Synergistic Activities

US Co-chair International Joint Commission's Science Advisory Board (Great Lakes Research Coordinating Committee)	2019-present
Member International Joint Commission's Science Advisory Board (Great Lakes Research Coordinating Committee)	2014-2019
Executive Director of LEARN (**L**ake **E**rie and **A**quatic **R**esearch **N**etwork); consortium of universities within Ohio working to promote collaborative research, education and networking to address the challenges and opportunities facing Ohio's freshwater resources (created under NSF planning grant)	2017-present
Member DEI Committee within National Association of Marine Labs	2021-present
Secretary, Sea Grant Association Executive Board	2017-present
Advisory Board of Ohio Water Research Center (USGS, federally-authorized and state-designated Water Resources Research Institute)	2015-present
Great Lakes Water Quality Agreement Annex involvement: Annex IV Objectives and Targets Task Team (Nutrient Annex)	2016-present
Annex II Lakewide Management Extended Subcommittee	2016-present
Advisory Board of the Cleveland Water Alliance (CWA); previously CWA Program Committee	2016-present
Agency Partner for Ohio Lake Erie Commission	2015-present
Co-Director of Lake Erie Millennium Network	2016-present

Committee member of Lake Erie Partnership Working Group 2015-present
Council member (Ex-officio) Old Woman Creek National Estuarine Research Reserve Advisory 2016-2018

Key Honors

Sea Grant and Stone Lab staff PI's, under Director's leadership, awarded numerous grant submissions totaling >$10M since fiscal year 2019

Sea Grant and Stone Lab programs manage research competitions and funded projects for state and federal partners in excess of $11M (>100 projects awarded to >35 principal investigators at >10 institutions)

Key Peer-Reviewed Publications

Wilson, RS, M Beetstra, JM Reutter, G Hesse, K DeVanna-Fussell, LT Johnson, KW King, GA LaBarge, JF Martin, and **CJ Winslow.** (2019). Commentary: Achieving Phosphorus Reduction Targets for Lake Erie. *Journal of Great Lakes Research*. 45(1):4-11.

Davis, TW, R Stumpf, GS Bullerjahn, RM McKay, JD Chaffin, TB Bridgeman, and **CJ Winslow**. (2018). Science meets policy: A framework for determining impairment designation criteria for large waterbodies affected by cyanobacterial harmful algal blooms. *Harmful Algae*. 81:59-64

Steinhart, GB, S Bode, J Thieme, and **CJ Winslow**. (2017). Fish Passage through Three Types of Structures in Diked Coastal Lake Erie Wetlands. *North American Journal of Fisheries Management*. 37(3):497-509

C. Current and pending support

D. Data management plan

In our 2017 CI proposal to NOAA, we outlined a data management plan that identified when, how, and where environmental data are shared based on the type of data collected. Since that time we, have worked with NOAA GLERL's Data Manager, Lacey Mason, to expedite and better organize how we make our data available. This effort has dramatically increased the volume of new National Centers for Environmental Information (NCEI) records originating from our collective research, including data that were collected by CIGLR and NOAA GLERL prior to the start of the current CI. Specific details of our current data sharing practices are listed below, along with recent examples for specific products.

Observing systems data: These data are collected from our regionally-distributed network of nearshore and open-water automated instruments (e.g., buoys, mooring stations, mobile platforms, remote sensing) and are mostly associated with research projects in Theme 1.

1. Timeline for making data available. Observing data are transmitted in real time where possible to the Great Lakes Observing System (GLOS) Data Portal, National Data Buoy Center (NDBC), or the GLERL Real Time Coastal Observation Network (ReCON) data system. Systems which do not allow real-time transmission (e.g., underwater moorings) are offloaded and processed as available. Glider data have been submitted in delayed mode to date, and the addition of decimated real-time transmission to the Integrated Ocean Observing System (IOOS) Glider Data Assembly Center (DAC) is planned for 2021.

2. Methods for providing data access. Data are publicly disseminated through the Great Lakes Observing System (GLOS) Data Portal. Data can be accessed directly through web services for the advanced user, or via specialized tools that allow users to search, view, and download data. The web portal also provides search access to metadata from partner stations and from the GeoNetwork. GLOS serves the Great Lakes region as a data management resource using a standards-based service-oriented architecture. These data streams are routed to the World Meteorological Organization Global Telecommunication System (WMO GTS) through NDBC to promote open data sharing, and are archived with NCEI. Glider data are publicly disseminated through the IOOS National Glider DAC. CIGLR works with GLERL to deposit datasets from other projects directly into NOAA's NCEI, where they are accessible, discoverable, and accompanied by metadata and context. Some other datasets (e.g., Michigan Tech Research Institute optical properties field data) are provided after processing and QC in a publicly-available repository (http://glopgd.org/).

3. Standards for data/metadata format and content. CIGLR adopts the data and metadata standards according to where it is deposited. Data are provided in tabular format or, when appropriate, using NetCDF templates. For large data centers such as NCEI, we follow the formats required for metadata. GLOS uses data and metadata standards adopted IOOS, which makes data and metadata available through their Data Management and Communications (DMAC) system.

4. Volume of data collected. Observing system data volume is on the order of 100 gigabytes/year.

5. Prior experience making data available. GLOS buoys operated by CIGLR have provided data to GLOS and NDBC in real-time since 2011. Real-time nutrient buoys in western Lake Erie began transmitting data to the GLERL ReCON system and GLOS in 2015. Glider data collected from 2012 to 2018 were disseminated to interested researchers, but were not

publicly discoverable until 2019 when the entire backlog was processed and submitted to the IOOS Glider DAC. 2019 data were submitted to the DAC within two weeks of glider recovery, and CIGLR assisted the University of Windsor in submitting the first bi-national glider data to IOOS in 2020.

Ecological and social science data: These data involve the collection of new samples (e.g., biological samples or survey data) or the collation of existing data into larger datasets. These data are mostly associated with research projects in Themes 2 and 4.

1. Timeline for making data available. Unlike data from observing systems, much of which are made available in near real time, ecological and social data must be manually processed and analyzed by scientific staff. As such, there is a time lag between when samples or information are collected, and when data can be made available. This time delay differs by the type of project, as well as the type of data collected. Data are made available prior to or upon publication, within two years of the end of the project performance period, or two years after the data are collected and verified, whichever is earliest.

2. Methods for providing data access. CIGLR works with NOAA GLERL to deposit datasets from most projects into NOAA's NCEI, where they are accessible, discoverable, and accompanied by metadata and context. Some other datasets (e.g., laboratory experiments) are provided as data and metadata with the published article or in an open-access public repository (e.g., Dryad). Sequencing data from our 'omics project are deposited, with metadata, in the National Center for Biotechnology Information (NCBI) BioProject where they are accessible and discoverable through sequence searching. Data from social science and stakeholder engagement activities are subject to the University of Michigan Institutional Review Board (IRB) for Health Sciences and Behavioral Sciences data security guidelines. Specifically, human subject anonymized data are provided in or alongside published work and personally identifiable information is kept in a secure file (password protected) for the duration of the study and destroyed after analysis. Data that are collected for internal review purposes only are managed according to best practices issued by the university's IRB for human study data. Testimonials or quotes gathered from stakeholders are not shared externally without recorded approval, and are subject to review by the stakeholder prior to public release.

3. Standards for data/metadata format and content. CIGLR adopts the data and metadata standards according to where it is deposited. Data are provided in tabular format or, when appropriate, using NetCDF templates. For large data centers such as NCEI, we follow the formats required for metadata. For datasets that accompany our peer reviewed publications or are deposited in public data repositories other than NCEI, we provide metadata that, at a minimum, address the "who, what, why, where, when, and how" questions.

4. Volume of data collected. The volume of ecological and social data to be collected by CIGLR and its Regional Consortium (on NOAA-funded projects) is less than 1 terabyte per year, and the majority of this is sequence data.

5. Prior experience making data available. Prior to depositing our monitoring data in NCEI, CIGLR had extensive experience responding to data requests from individuals. Now those requests are directed to the appropriate NCEI accession. CIGLR data management programmers have developed several web-based data portals and have over 8 years of

experience working with NOAA GLERL to ingest, quality assure, archive, and disseminate both environmental data and metadata. We have worked with NOAA over the past 20 years to develop project specific, web-accessible, searchable databases for internal and external sharing of results.

Modeling and forecasting data: These data generally represent the output of statistical models or numerical simulations that use historical data collected from observing systems, or biological data from monitoring efforts and experiments, to predict the future state of a dependent variable of interest (e.g., fisheries, hypoxia, harmful algal blooms, temperature, currents, ice, waves, water level). These data are mostly associated with research projects in Theme 3.

1. Timeline for making data available. Modeling and forecasting data are generally based on data that are already publicly available. However, CIGLR aims to make newly-derived data, modeling code, and outputs publicly available immediately after publication, or a maximum of 2 years after the end of the project performance period.

2. Methods for providing data access. Models tend to be project specific, and the forecasts tend to focus on specific end users (e.g., public water managers). All model output to be used in operational forecasts follows requirements of the NOAA operational program centers, such as the Great Lakes Operational Forecast System (GLOFS). We work with GLOS for models supporting research and public information. GLOS ingests, stores, and serves model nowcasts and forecasts through a service-oriented architecture, based on standardized tools such as 52North Sensor Observation Service (SOS), Thematic Real-time Environmental Distributed Data Services (THREDDS), NOAA Environmental Research Division's Data Access Program (ERDDAP) and more, and will build on its existing GeoNetwork Metadata Catalog and the GLOS Data Portal to maintain query capacity and delivery of well-curated data in useful formats that are discoverable, accessible, and usable in accordance with the IOOS/DMAC.

3. Standards for data/metadata format and content. Guidance and standards from NOAA are largely geared toward data that will be served to the public, especially through dedicated data centers. CIGLR makes the strongest practical effort at documenting the method of generating the data, including the information on where, when, and how it was generated, along with links to peer-reviewed and other literature, and practical considerations of parsing the data. Standardized datasets that are served to external users using current formatting standards acceptable to the broader scientific community. This should make them usable off the shelf by standard analysis software, such as ArcGIS.

4. Volume of data collected. The volume of modeling and forecasting data generated is 101 – 102 terabytes per year.

5. Prior experience making data available. For nearly 30 years, the CI has supported NOAA GLERL with modelers, programmers, and data managers that have helped to develop web-based products and services for cataloging, archiving, and disseminating model output and develop model output products designed for specific public applications.

Examples of Recent Data Sharing. Under the current CI, we have made new NCEI depositions for water quality data collected for our HAB research and buoys in Lake Erie (doi:10.25921/11da-3x54), HAB research in Saginaw Bay (NCEI Accessions 0220469, 0189250, 0209220), and moorings from our hypoxia project (doi: 10.25921/qd27-bj97). Glider "glos_236" data are available at

https://gliders.ioos.us/map/# and https://data.ioos.us/organization/glider-dac. These data are accessible, discoverable, and meet the standards set forth by NCEI. Additionally, CIGLR has been distributing via email a weekly data share from our Lake Erie HAB monitoring program, which is used by other researchers, stakeholders including public water utilities, and the NOAA Lake Erie Harmful Algal Bloom Forecast (formerly the HAB Bulletin). Examples of sequence data from our 'omics research are available in NCBI under BioProject PRJNA385848 or specific sequence reads referenced in the publications (e.g., SRP117911, SRP117914, and SRP117915).

E. Appendices

Appendix 1 – List of Prior Awards

Project	Relevance	Agency	PI name	Role	Institution	Period	Award Number(s)	Amount
CAREER: Molecular Studies of Phase Separations and Internal Structure in	Themes 1, 3-4	NSF	Ault	PI	U. Mich.	2017-22	1654149	$ 594,999
Collaborative Research: Marine Aerosols in the Arctic: Linking surface water chemistry and	Themes 1, 3-4	NSF	Ault	PI	U. Mich.	2017-22		$ 383,675
Sloan Research Fellowship	Themes 1-4	Sloan Foundation	Ault	PI	U. Mich.	2018-22	FG-2018-10226	$ 65,000
To examine the pH of indoor surfaces	Theme 4	Sloan Foundation	Ault	PI	U. Mich.	2018-23	G-2018-11239	$ 300,000
Collaborative Research: Organosulfate Multiphase Chemistry and Physicochemical Properties: Oxidation and Sulfate Recycling in	Themes 1, 3-4	NSF	Ault	PI	U. Mich.	2021-2024	2040610	$ 425,014
Size-resolved Organic Aerosol Composition, Sources, and Characteristics in Urban Areas	Themes 1, 3-4	NOAA	Ault	PI	U. Mich.	2021-2024	NA21OAR4310136	$ 371,696
Wearable Microsystem for Continuous Personalized Aerosol Exposure Assessment	Themes 1, 3-4	Michigan State University (Direct); NIH (Prime)	Ault	Co-PI	U. Mich.	2021-2026	RC113197B	$ 657,853
Linking genes to microbial traits key to the rise and demise of cyanobacterial harmful	Themes 1 & 3	NOAA (Omics)	Denef	PI	U. Mich.	2019-2022		$ 434,784
Understanding the genetic traits and gene-environment interactions that determine feeding resistance to invasive dreissenid mussels by toxic cyanobacterial bloom-	Themes 1-3	NOAA	Denef	PI	U. Mich.	2018-2022		$ 315,887
Identifying microbiological factors driving botulism outbreaks at Sleeping Bear Dunes	Themes 1 & 4	DOI (NPS)	Denef	PI	U. Mich.	2018-2022	P18AC00009	$ 179,869
'Omics-informed mapping of Microcystis predation defense trade-offs to improve Great Lakes harmful algal bloom models	Themes 1-3	NOAA (Michigan Sea Grant)	Denef	PI	U. Mich.	2022-2024		$ 180,000
Microbiome control over eukaryotic species	Themes 1-3	NSF	Denef	PI	U. Mich.	2022-2025		$ 530,000
Collaborative Research: Revealing the interplay between light, sulfur cycling, and	Themes 1-4	NSF	Dick	PI	U. Mich.	2016-2022	1637066	$ 408,147
The role of heterotrophic bacteria in protecting cyanobacteria from hydrogen	Themes 3 & 4	NSF	Dick	PI	U. Mich.	2018-2022	1736629	$ 874,085
Linking process models and field experiments to forecast algal bloom toxicity in Lake Erie	Themes 1 & 3	Ohio State University/NOAA	Dick	PI	U. Mich.	2018-2022	60066871	$ 51,293

Project	Relevance	Agency	PI name	Role	Institution	Period	Award Number(s)	Amount
Discovery and characterization of new toxins in genomes and metagenomes of bloom-forming cyanobacteria	Themes 1-3	Bowling Green State University/NSF	Dick	PI	U. Mich.	2018-2023	10010192-UM05	$ 338,705
P01: Host and Microbial Metabolism in Graft versus Host Disease	Theme 4	National Heart, Lung, and Blood Institute (NHLBI)	Dick	PI	U. Mich.	2020-2025	5 - P01 - HL - 149633 - 02	$ 1,014,000
Microbiome controls on harmful algal toxin production in Lake Erie	Themes 1, 3-4	University of Toledo/Lawrence Livermore National Laboratory	Dick	PI	U. Mich.	2020-2023	F-2021-6	$ 144,000
Cooperative Institute for Great Lakes	Themes 1-4	NOAA	Dick	PI	U. Mich.	2017-2022	NA17OAR4320152	$ 30,000,000
Global Water Futures Observatories	Themes 1-4	Canadian Foundation for Innovation - Major Science Intitatives	Fisk	Co-PI	U. Windsor	2023-2029		$41,088,700 CDN
Quantifying sources of mortality and behavior of stocked fish across release depths in Lake Ontario: using acoustic telemetry and genomics to inform stocking methods	Theme 2	USFWS Great Lakes Fish and Wildlife Restoration Act Funding	Fisk	PI	U. Windsor	2022-2024		$ 243,023
Impacts of aquatic invasive species and climate change on Lake Ontario food webs	Theme 2	OMNRF	Fisk	PI	U. Windsor	2022-2025		$120,000 CDN
Ecosystem-based fishery management model -	Themes 2-4	OMNRF	Fisk	PI	U. Windsor	2022-2024		$165,000 CDN
Does barotrauma reduce the efficacy of stocking deepwater fishes?	Theme 2	GLFC - Fisheries Research	Fisk	PI	U. Windsor	2022-2024		$181,000 CDN
Predicting fish production from lake size using novel measurement strategies of fish	Theme 2	NSERC Alliance	Fisk	PI	U. Windsor	2021-2025		$ 462,811
Effects of restoring energy and nutrient dynamics on the fishery production in the Boardman River	Themes 2-4	GLFC - Fisheries Research	Fisk	PI	U. Windsor	2021-2024		$ 327,260

Project	Relevance	Agency	PI name	Role	Institution	Period	Award Number(s)	Amount
Using real-time, continuous, and high-frequency water quality data to develop early warning systems for water security in the	Themes 1-4	NSERC Alliance	Fisk	PI	U. Windsor	2021-2024		$1,000,070 CDN
Real Time aquatic ecosystem observation network (RAEON)	Theme 1	Canadian Foundation for Innovation - Innovation Fund	Fisk	PI	U. Windsor	2018-2023		$ 12,417,530
Changing Great Lakes Ecosystems	Theme 2 & 4	Canada Research Chairs	Fisk	PI	U. Windsor	2017-2024		$1,400,000 CDN
COLLABORATIVE PROPOSAL: Feeling the Squeeze: How Financial Stress Shapes Decision Making and Risk for Drinking Water	Theme 4	NSF DRMS	Hughes	PI	U. Mich.	2021-2024	2048505	$ 218,063
Environmental Modeling: Integrating	Theme 3	CIGLR / NOAA	Jablonowski	PI	U. Mich.	2018-2022	NA17AOR4320152	$ 246,017
Improving Lake-Effect Snow Forecasting Capabilities via Advanced Coupling	Theme 3	CIGLR / NOAA	Jablonowski	PI	U. Mich.	2019-2022	NA19OAR4590140	$ 614,988
Unified Forecast System R2O Project: Advancing NOAA's Coupled Model	Theme 3	CIGLR / NOAA	Jablonowski	PI	U. Mich.	2020-2022	NA17AOR4320152	$ 293,998
Supporting decision-making for a vital waterway in the Great lakes by machine learning model-based lake ice forecasting	Theme 3	Michigan Institute for Data Science (University of Michigan)	Jablonowski	PI	U. Mich.	2021-2022		$ 30,000
CLDERA -- CLimate impact: Determining Etiology thRough pAthways	Theme 3	Sandia National Laboratories (Direct) / Department of Energy (Prime)	Jablonowski	PI	U. Mich.	2021-2024	2305233	$ 418,204
2021 Synthesis, Observation, and Response	Theme 1	NOAA GLERL	Johengen	PI	U. Mich.	2021-2022	NA17AOR4320152	$ 754,988
2021 Implementation of the GLOS Buoy and Mobile Platform Observing System	Theme 1	NOAA GLERL	Johengen	PI	U. Mich.	2021-2022	NA17AOR4320152	$ 218,001

Project	Relevance	Agency	PI name	Role	Institution	Period	Award Number(s)	Amount
Alliance for Coastal Technologies	Theme 1	NOAA IOOS	Johengen	PI	U. Mich.	2021-2022	NA16NOS012OO; SA7525796B	$ 185,000
MERHAB19: Portable toxin detection technology to support GL decision support	Theme 1	NOAA MERHAB	Johengen	PI	U. Mich.	2019-2022	NA17AOR4320152	$ 131,648
Michigan Sea Grant 2022-2024 Omnibus Proposal	Themes 1-4	National Sea Grant Program	Johengen	PI	U. Mich.	2022-2024	NA16NOS012OO	$ 3,332,864
SCC-IRG Track 1: Overcoming Social and Technical Barriers for the Broad Adoption of	Theme 4	NSF	Kerkez	PI	U. Mich.	2017-2022	1737432	$ 2,182,772
Assessing the Integration of Real Time Control (RTC) Water Management Systems into GLWA's Long Term Control Plan	Theme 4	Great Lakes Water Authority	Kerkez	PI	U. Mich.	2020-2022	Contract No. 2001434	$ 636,702
Lake St. Clair and Clinton River Watershed Decision Support System - University of Michigan	Theme 1 & 4	Department of Environment, Great Lakes and Energy / EPA	Kerkez	PI	U. Mich.	2020-2022	2020-2509	$ 902,000
CAREER: Toward a Theory for Smart Stormwater	Theme 1 & 4	NSF	Kerkez	PI	U. Mich.	2018-2023	1750744	$ 500,000
Low-cost Wireless Sensing of Scour Critical Bridges	Theme 1 & 4	Michigan Department of Transportation	Kerkez	PI	U. Mich.	2021-2023	2019-0312	$ 446,297
RAISE:Neighborhood Environments as Socio-Techno-bio Systems: Water Quality, Public	Theme 4	NSF	Kerkez	PI	U. Mich.	2017-2023	1744724 - Supplement	$ 1,168,826
IRES: Advancing Cyber-Enabled, Decentralized Water Systems in Rapidly Developing Cities	Theme 4	NSF	Kerkez	PI	U. Mich.	2017-2022	1658650	$ 249,989
NSF AccelNet: AccelNet Implementation: International Network For Researching, Advancing and Assessing Materials for	Themes 1-4	NSF	Klaper	Co-PI	UW-Milwaukee	2022-2027		$ 1,687,679
NSF Center for Sustainable Nanotechnology	Themes 1-4	NSF	Klaper	PI	UW-Milwaukee	2020-2025		$ 20,000,000
Great Lakes Regional Integrated Sciences and	Themes 1-4	NOAA	Lemos	PI	U. Mich.	2015-2022	NA15OAR4310148	$ 4,098,836
Making Gulf Communities More Resilient: Scaling-up a Customized Vulnerability Assessment Template for Extreme Events in	Themes 1-4	National Academy of Sciences	Lemos	PI	U. Mich.	2019-2022	NAS Grant Number 200010878	$ 2,190,668

Project	Relevance	Agency	PI name	Role	Institution	Period	Award Number(s)	Amount
NERRS Science Collaborative: A comprehensive national program for end user	Themes 1-4	NOAA	Lemos	PI	U. Mich.	2019-2024	NA19NOS4190058	$ 20,000,000
Great Lakes Regional Integrated Sciences and Assessments Center (Bridge Year)	Themes 1-4	NOAA	Lemos	PI	U. Mich.	2020-2022	NA20OAR4310148A	$ 856,944
Great Lakes Regional Integrated Sciences and	Themes 1-4	NOAA	Lemos	PI	U. Mich.	2021-2026	NA21OAR4310307	$ 5,399,999
GLISA Consulting Service for Consumers Energy	Themes 1-4	Consumers Energy Company	Lemos	PI	U. Mich.	2021-2022	Research Agreement	$ 10,000
Linking environmental metagenomics, eDNA monitoring and hydrodynamic, fate and transport modeling for the Great Lakes	Themes 1-4	US Department of the Interior, USGS	Mantha	PI	MSU	2017-2022		$ 499,999
Cladophora in the Great Lakes: Field observations and modeling	Themes 2 & 4	US Department of the Interior, USGS	Mantha	PI	MSU	2019-2024		$ 425,000
Enhancement of the RHEAS capabilities for monitoring and predicting rice yields in the	Theme 4	NASA	Mantha	PI	MSU	2020-2022		$ 511,824
Building capacity at LSSU's Center for Freshwater Research and Education	Themes 1-4	US Economic Development Administratio n	Moerke	PI	LSSU	2021-2023		$ 956,858
Food Web and Brook Trout Assessment of Lake Superior	Theme 2	US Environmenta l Protection Agency	Moerke	PI	LSSU	2021-2023		$ 75,000
Effects of Didymosphenia geminata blooms on salmonid productios in Michigan waters	Theme 2	Michigan Dept. of Natural Resources	Moerke	PI	LSSU	2021-2025		$226,929 (subaward)
Learning to manage blooms of Rock Snot, an ecologically disruptive diatom, in Michigan waters	Theme 2	Michigan Invasive Species Grant program (DNR)	Moerke	PI	LSSU	2021-2024		$ 293,500
St. Marys River Green Stormwater Demonstration Project	Theme 4	USDA Forest Service	Moerke	PI	LSSU	2021-2022		$ 250,000

Project	Relevance	Agency	PI name	Role	Institution	Period	Award Number(s)	Amount
Increasing freshwater and data literacy among high school students through real-	Theme 4	NOAA B-Wet	Moerke	PI	LSSU	2021-2022		$ 79,620
Human impacts on Great Lakes watersheds: Developing Great Lakes stewards in urban	Theme 4	NOAA B-Wet	Moerke	PI	LSSU	2019-2022		$ 76,575
Expanding the MiWaterNet initiative to implement water sensors in the Eastern Upper Peninsula	Themes 1 & 4	Michigan Department of Natural Resources	Moerke	PI	LSSU	2021-2022		$ 35,000
Measuring and Managing Risks to Both Property and Nature along Great Lakes Coastal Shores	Theme 4	University of Michigan Graham Sustainability Institute	Norton	PI	U. Mich.	2022		$ 10,000
NERRS Science Collaborative: A comprehensive national program for end user	Theme 4	NOAA	Read	PI	U. Mich.	2019-2024	NA19NOS4190058	$ 19,902,009
Great Lakes Biological Monitoring	Theme 2	EPA Great Lakes National Program Office	Rudstam	PI	Cornell U.	2017-2022		$ 6,000,000
Warmwater fisheries	Theme 2	New York Department of Environmental Conservation	Rudstam	PI	Cornell U.	2021-2024		$ 1,600,000
Biomonitoring in Lake Ontario	Theme 2	New York Department of Environmental Conservation	Rudstam	PI	Cornell U.	2021-2025		$ 120,000
Acoustic analysis in Great Lakes	Theme 1 & 2	USGS Great Lakes Laboratory	Rudstam	PI	Cornell U.	2022-2024		$ 120,000
Cisco and lake whitefish dynamics in the Great Lakes	Theme 2	Great Lakes Fisheries Commission	Rudstam	PI	Cornell U.	2022-2025		$ 230,000

Project	Relevance	Agency	PI name	Role	Institution	Period	Award Number(s)	Amount
Green Lake Cisco Protection	Themes 2 & 4	MI Dept of Natural Resources	Steinman	PI	GVSU	2020-2022		$ 135,000
Great Lakes Long-Term Ecological Research	Theme 4	NOAA	Steinman	PI	GVSU	2022		$ 127,500
Restoring the Macatawa Watershed	Theme 4	Various	Steinman	PI	GVSU	2015-2025		$ 500,000
Water quality for Church Lake	Theme 4	Church Lake Homeowners Association	Steinman	PI	GVSU	2020-2022		$ 17,350
Long-term monitoring of Muskegon Lake	Theme 4	Community Foundation for Muskegon County	Steinman	PI	GVSU	ad infinitum		$ 10,000
Lake Superior monitoring and research at Apostle Islands National Lakeshore	Theme 2 & 4	CRTP - Resources of the National Park System	Sterner	PI	U. Minn. Duluth	2017-2022		$ 377,516
RCN: The climate and governance variability in the Great Lakes (CGVG) Project	Themes 1-4	NSF	Sterner	PI	U. Minn. Duluth	2020-2022		$ 499,989
Aquatic N2-Fixation Research Coordination Network (ANF-RCN)	Themes 1 & 3	NSF	Sterner	PI	U. Minn. Duluth	2020-2025		$ 499,700
Climate, Storms, and the Drivers of Cyanobacteria Blooms in Lake Superior	Themes 1-3	NECASC-USGS	Sterner	PI	U. Minn. Duluth	2021-2023		$ 290,134
Stoichiometry meets genomics: assessing limiting factors for diverse CHABs & associated toxins	Themes 2 & 3	National Sea Grant Program	Sterner	PI	U. Minn. Duluth	2022-2024		$ 155,401
Sex-Specific Metabolic and Epigenetic Programming of Cardiac Differentiation by	Theme 4	NIEHS	Svoboda	PI	U. Mich.	2020-2023	5 - K01 - ES - 032048 - 02	$ 467,625
Environmental Epigenomics and Precision Environmental Health	Theme 4	NIEHS	Svoboda	PI	U. Mich.	2020-2028	5 - R35 - ES - 031686 - 02	$ 6,942,422
Continuation of the GLCWMP: 2020-2025	Theme 2	US EPA	Uzarski	PI	Central Mich. U.	2021-2025		$ 10,000,000
Continuing Assessment of Health of Michigan Palustrine Wetlands and Index	Theme 2	Michigan Dept. Environment, Great Lakes, and Energy (EGLE)	Uzarski	PI	Central Mich. U.	2020-2022		$ 120,000
Ohio Sea Grant College Program Omnibus	Themes 1-4	NOAA	Winslow	PI	Ohio St. U.	2018-2022		$ 9,289,317

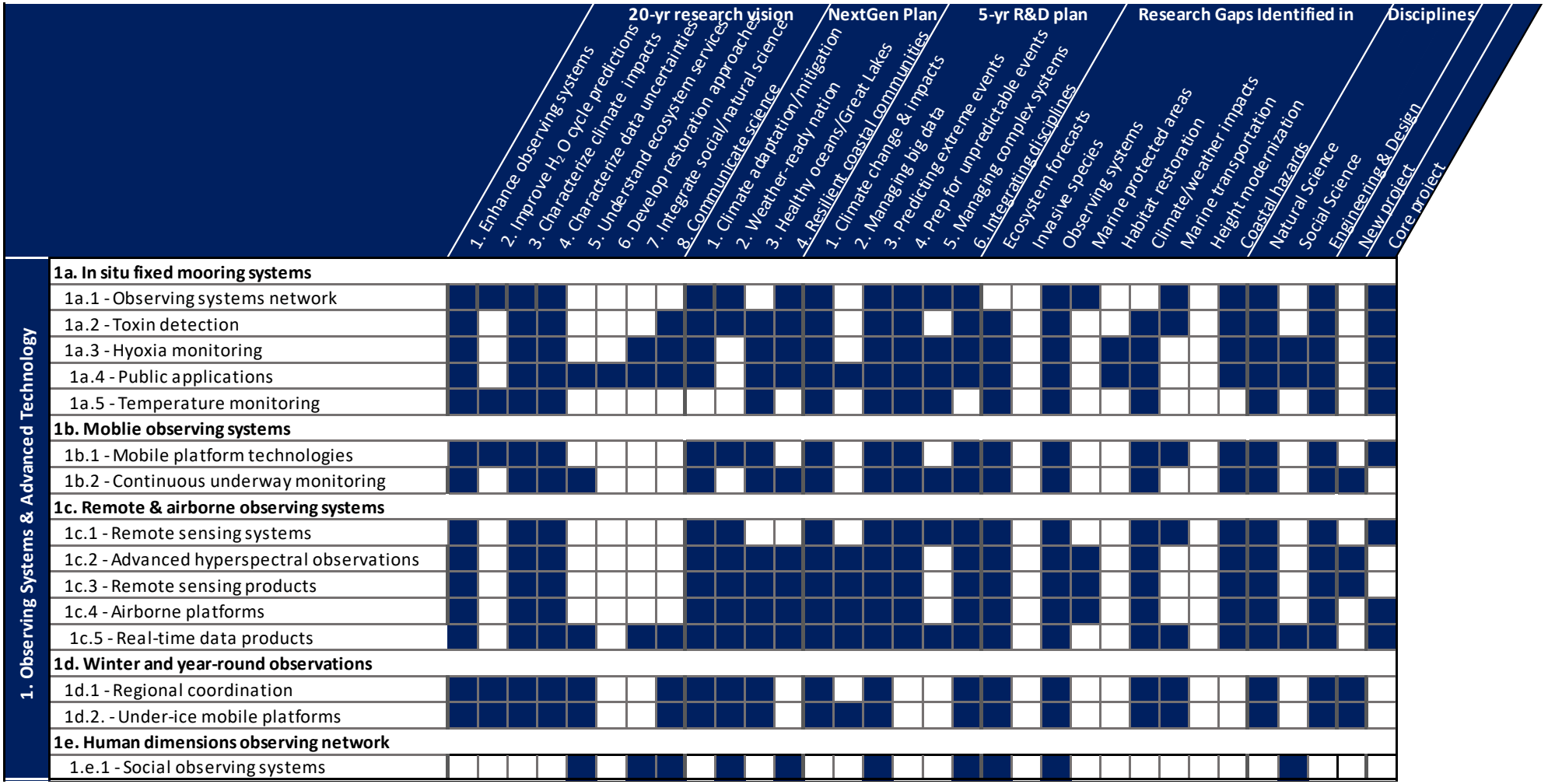
Project	Relevance	Agency	PI name	Role	Institution	Period	Award Number(s)	Amount
Ohio Clean Marinas Program: Cycle 25	Themes 1-4	Ohio Department of Natural Resources	Winslow	PI	Ohio St. U.	2021-2022		$ 138,724
H2Ohio Wetland Monitoring Program	Themes 1-4	Ohio Department of Natural Resources	Winslow	PI	Ohio St. U.	2020-2022		$ 3,326,400
ODHE Harmful Algal Bloom Research Initiative FY20 and 21	Themes 1-4	Ohio Department of Higher Education	Winslow	PI	Ohio St. U.	2020-2023		$ 8,000,000
FY2019 Ohio Department of Higher Education Harmful Algal Bloom Research Initiative	Themes 1-4	Ohio Department of Higher Education	Winslow	PI	Ohio St. U.	2019-2023		$ 3,385,825
Great Lakes Fisheries Science Training (FiST) workshop for undergraduates	Themes 2 & 4	NOAA	Winslow	PI	Ohio St. U.	2020-2022		$ 139,802
Expanding the Heidelberg tributary loading program	Themes 1, 3-4	Ohio EPA	Winslow	PI	Ohio St. U.	2017-2022		$ 500,000
Knauss Fellowship Application 2021 - James	Themes 1-4	NOAA	Winslow	PI	Ohio St. U.	2021-2022		$ 59,000
Great Lakes Air Deposition Mercury Monitoring Services 2021-2023	Themes 1 & 3	Ohio EPA	Winslow	PI	Ohio St. U.	2021-2023		$ 27,769
Extending impact of U.S. EPA's Great Lakes National Program Office using Sea Grant	Themes 1-4	Purdue University	Winslow	PI	Ohio St. U.	2020-2022		$ 100,580
Great Lakes Fisheries Science Training (FiST) workshop for undergraduates	Themes 2 & 4	NOAA	Winslow	PI	Ohio St. U.	2020-2022		$ 139,802
Knauss Fellowship Application 2021 -	Themes 1-4	NOAA	Winslow	PI	Ohio St. U.	2021-2022		$ 59,000
Knauss Fellowship Application 2021 - Kerri	Themes 1-4	NOAA	Winslow	PI	Ohio St. U.	2021-2022		$ 59,000
Knauss Fellowship Application 2021 - Helena	Themes 1-4	NOAA	Winslow	PI	Ohio St. U.	2021-2022		$ 59,000

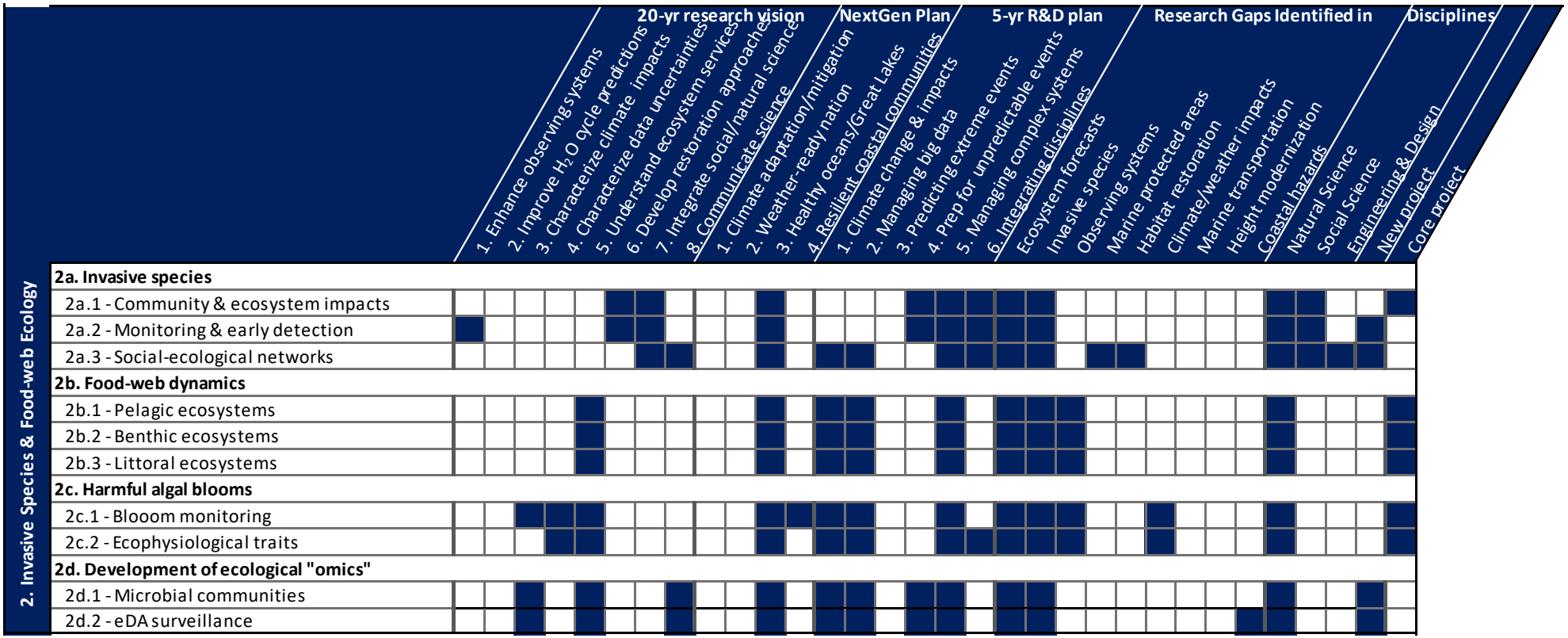
Appendix 2 – Research Capacity of Regional Consortium

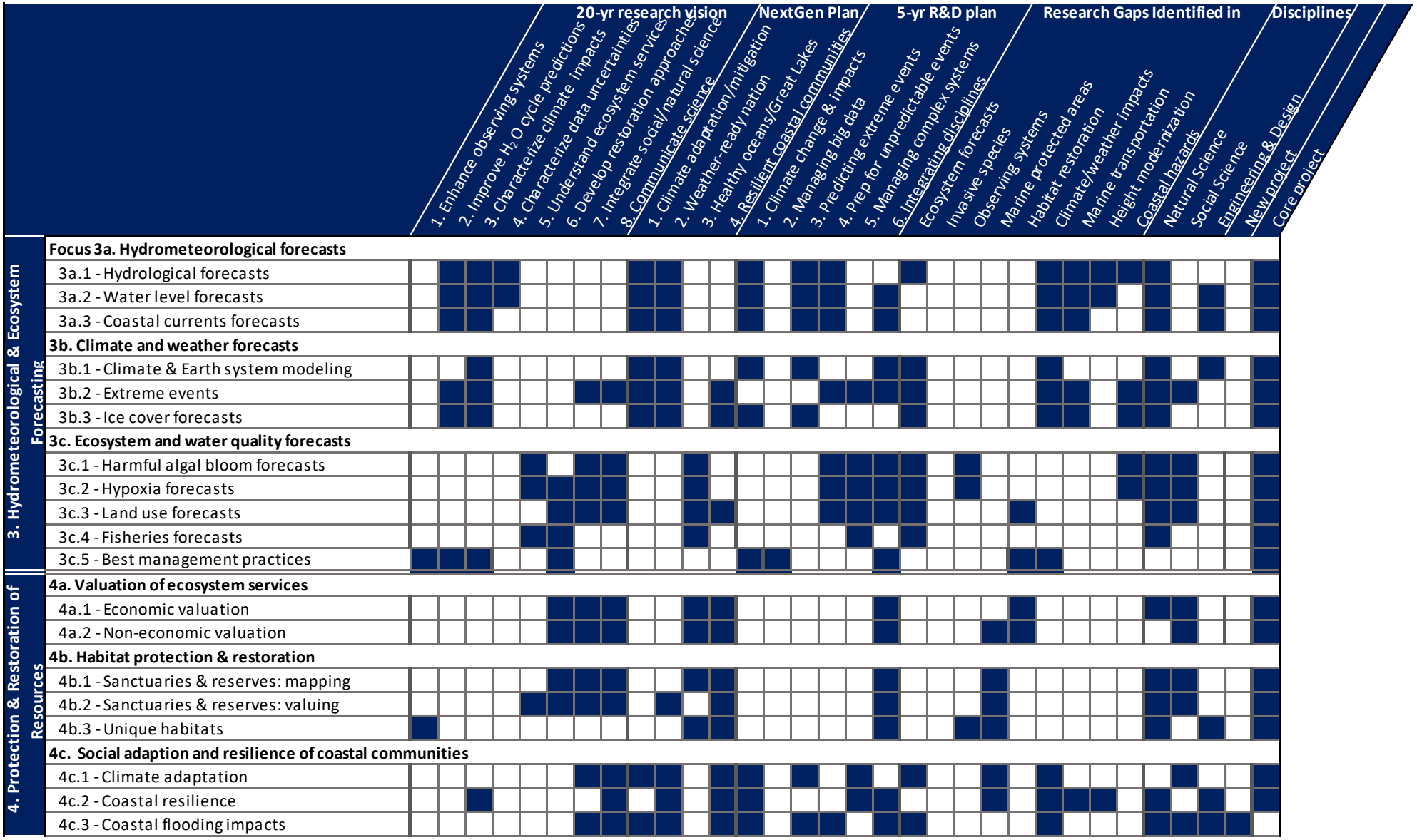
		Central Michigan University	Cornell University	Grand Valley State University	Lake Superior State University	Michigan State University	Ohio State University	University of Michigan	University of Minnesota Duluth	University of Windsor	University of Wisconsin Milwaukee
Research Vessels		38' *Chippewa* 7 small vessels	29' Trawler 5 small vessels	66' *W.G. Jackson* 45' *D.J. Angus* 4-6 small vessels	4 small vessels	---	47' *Gibraltar III* 37' *M/V BioLaB* 34' *Carmen* 27' *Echo* 3 small vessels		86' *Blue Heron* 25' *Kingfisher*	---	71' *Neeskay* 4 small vessels
Observing Systems		Ship-based system (L Michigan)	1 buoy (Oneida L)	1 buoy (Muskegon L), 5 ROVs	1 AUV, 1 ROV, MIWaterNet, sensors on 15 Great Lakes tributaries	1 glider (regional)	1 buoy (L Erie) 2 ROVs (L Erie)	9 buoys (L Erie, L Michigan, L. Huron, Little Traverse Bay); 2 AUVs (regional); 2 gliders (regional)	3 buoys (L Superior) 2 gliders (L Superior)	4 gliders (regional)	2 buoys (L Michigan); 1 buoy (Green Bay); 2 ROVs, Ship-based system (L Michigan)
Field Research Stations	**Facility**	CMUBS: 130 ac, boat house, 4 labs, library, cafeteria	CBFS: 500 ac, 20 buildings, labs	AWRI: 14,000 ft² with 8 labs, vessel docks, meeting & office space, library	CFRE: 20,000 ft² with 6 labs, 1 production fish hatchery, meeting & office space, work cafe, Great Lakes Discovery Center	KBS: 17 km² bio-station, 3600 ft² greenhouse, 12 labs, library	StoneLab: 16ac biostation, vessel docks, 3,000 ft² lab space, office & meeting space, cafeteria, library	UMBS: 10,000 ac biostation, 24,000 ft² lab space, dining hall, library	LLO: 224 ac campus on L Superior, analytical labs	PERC: 22 ac research center, Point Pelee FERC: 3300 ft² center, Detroit R	GLWI: 160,000 ft² facility, 30 labs, deep water dock, ship staging area
	Experi-mental Facili-ties	350 gal (12) climate cont aquaria	800 gal (16) climate cont aquaria	350 gal (12) climate cont aquaria	270 gal (18) climate cont aquaria, 15 gal and 50 gal tank rack systems	30 m dia ponds (18)	450 gal tanks (4), 75 gal climate cont streams (2), 2500 L pools (54), 30 m hatcheries (2)	10 L (180) climate cont algal chemostats 1000 L (160) tanks	---	3000 L (18) climate cont aquaria 40 x 60 x 2 m deep ponds (4)	Aquaculture center Aquarium facilities
	Hous-ing	12 cabins, 1 dorm, sleeps 146	Cabins & dorms, sleeps 40	---	---	3 cabins, 12 dorms, 30 apts, sleeps 100+	2 cottages, 12 dorm suites, 12 houses, sleeps 90	100 cabins, 14 dorms, sleeps 300+	---	---	---
	Class-rooms	3	2	2	2	6	6	17	1	---	6
Specialized Laboratories and Facilities		Biomolecular; Engineering/ design; Gas (volatile, & semi-volatile) spectroscopy: HP computing	Bioacoustics: Biomolecular: Engineering/ design; Satellite imagery; GIS; Remote sensing	Biomolecular; Engineering/ design; Satellite imagery; GIS; Remote sensing; Sedimentology	Aquaculture, microscopy, water analysis, robotics engineering	Biomolecular; Engineering/ design; HP computing; Stable Isotopes; Satellite imagery; GIS; Remote sensing	Biomolecular; Engineering/ design; Radioisotope; HP computing; Satellite imagery; GIS; Remote sensing	Aquaculture; Biomolecular; Engineering/ design; HP computing; Satellite imagery; GIS; Remote sensing	IRMS; LC-MS; XRF; Bio-molecular; Coring & core processing; Engineering/design	Biomolecular; Engineering/ design; HP computing; Satellite imaging; GIS; Remote sensing	Aquaculture; Biomolecular; Data visualization; Engineering/ design; HP computing; Radioisotope

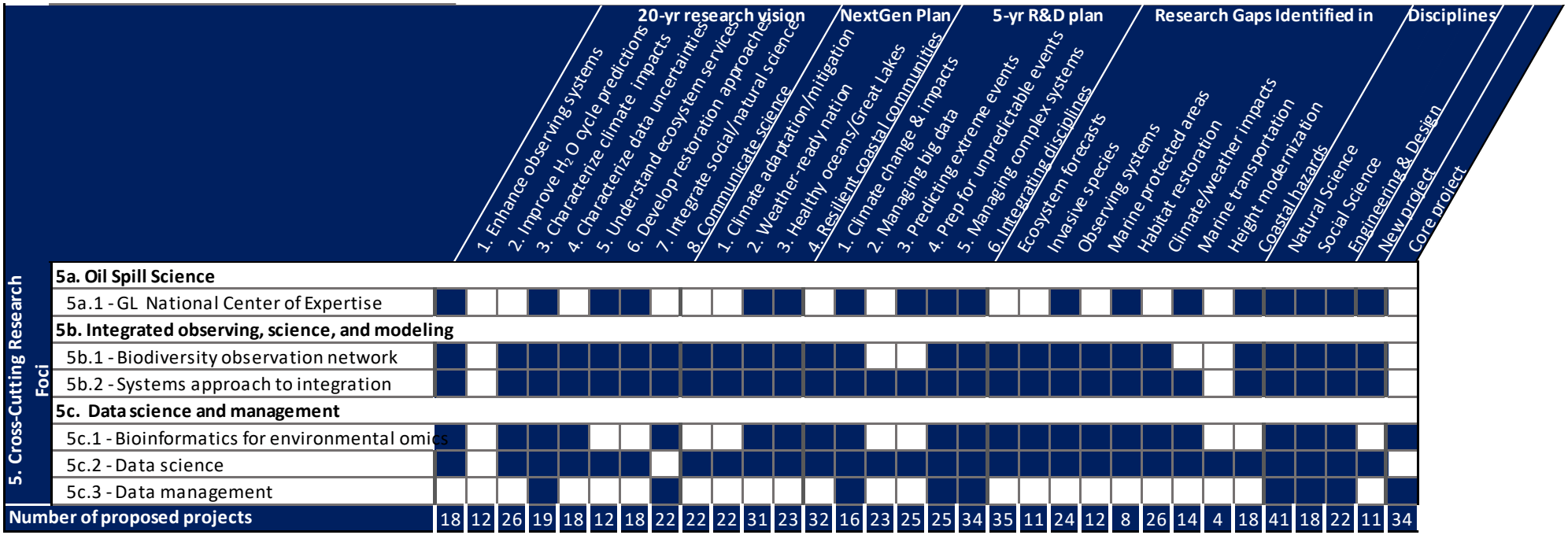
Number of NOAA related PhD and MS programs (examples)		5 (Earth Science, Ecosystem Science, Mathematics, Conservation Biology)	9 (Ecology, Aquatic Science, Wildlife Science, Policy)	3 (Biology, Aquatic Sciences)	— (undergraduate only)	10 (Fisheries, Ecology, Environ Science & Policy, Communication, Tourism, Protected Area Management)	12 (Ecology, Environ Social Science, Fisheries & Wildlife, Watershed Systems, Atmospheric Sci)	12 (Conservation, Human behavior, Sustainable Systems, Policy & Planning, Atmospheric & Oceanic Sci)	8 (Chemistry, Physics, Limnology & Oceanography, Geology, Conservation)	6 (Aquatic Ecotoxicology, Ecology, Invasion Biology, Biogeochemistry)	7 (Ecology, Ecotoxicology, Fish & Aquaculture, Environ Health, Water Law & Policy, Atmospheric Sci)
# of PIs in:	**ED/NS/SS**	0/25/0	2/19/10	0/13/2	3/6/0	4/15/9	11/10/4	12/18/7	0/12/0	2/13/2	5/23/8
	Theme 1-4	8/8/18/7	6/16/22/11	3/7/13/13	3/3/1/3	9/18/8/12	18/12/13/10	19/16/11/15	9/6/12/0	5/9/11/5	9/20/8/24

Appendix 3 – Mapping Projects to NOAA goals and FFO




2. Invasive Species & Food-web Ecology
20-yr research vision
NextGen Plan
5-yr R&D plan
Research Gaps Identified in
Disciplines
1. Enhance observing systems
2. Improve H2O cycle predictions
3. Characterize climate impacts
4. Characterize data uncertainties
5. Understand ecosystem services
6. Develop restoration approaches
7. Integrate social/natural sciences
8. Communicate science
1. Climate adaptation/mitigation
2. Weather-ready nation
3. Healthy oceans/Great Lakes
4. Resilient coastal communities
1. Climate change & impacts
2. Managing big data
3. Predicting extreme events
4. Prep for unpredictable events
5. Managing complex systems
6. Integrating disciplines
Ecosystem forecasts
Invasive species
Observing systems
Marine protected areas
Habitat restoration
Climate/weather impacts
Marine transportation
Height modernization
Coastal hazards
Natural Science
Social Science
Engineering & Design
New project
Core project
2a. Invasive species
2a.1 - Community & ecosystem impacts
2a.2 - Monitoring & early detection
2a.3 - Social-ecological networks
2b. Food-web dynamics
2b.1 - Pelagic ecosystems
2b.2 - Benthic ecosystems
2b.3 - Littoral ecosystems
2c. Harmful algal blooms
2c.1 - Blooom monitoring
2c.2 - Ecophysiological traits
2d. Development of ecological "omics"
2d.1 - Microbial communities
2d.2 - eDA surveillance


20-yr research vision
NextGen Plan
5-yr R&D plan
Research Gaps Identified in
Disciplines
1. Enhance observing systems
2. Improve H_2O cycle predictions
3. Characterize climate impacts
4. Characterize data uncertainties
5. Understand ecosystem services
6. Develop restoration approaches
7. Integrate social/natural sciences
8. Communicate science
1. Climate adaptation/mitigation
2. Weather-ready nation
3. Healthy oceans/Great Lakes
4. Resilient coastal communities
1. Climate change & impacts
2. Managing big data
3. Predicting extreme events
4. Prep for unpredictable events
5. Managing complex systems
6. Integrating disciplines
Ecosystem forecasts
Invasive species
Observing systems
Marine protected areas
Habitat restoration
Climate/weather impacts
Marine transportation
Height modernization
Coastal hazards
Natural Science
Social Science
Engineering & Design
New project
Core project
3. Hydrometeorological & Ecosystem Forecasting
Focus 3a. Hydrometeorological forecasts
3a.1 - Hydrological forecasts
3a.2 - Water level forecasts
3a.3 - Coastal currents forecasts
3b. Climate and weather forecasts
3b.1 - Climate & Earth system modeling
3b.2 - Extreme events
3b.3 - Ice cover forecasts
3c. Ecosystem and water quality forecasts
3c.1 - Harmful algal bloom forecasts
3c.2 - Hypoxia forecasts
3c.3 - Land use forecasts
3c.4 - Fisheries forecasts
3c.5 - Best management practices
4. Protection & Restoration of Resources
4a. Valuation of ecosystem services
4a.1 - Economic valuation
4a.2 - Non-economic valuation
4b. Habitat protection & restoration
4b.1 - Sanctuaries & reserves: mapping
4b.2 - Sanctuaries & reserves: valuing
4b.3 - Unique habitats
4c. Social adaption and resilience of coastal communities
4c.1 - Climate adaptation
4c.2 - Coastal resilience
4c.3 - Coastal flooding impacts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4. Resilient coastal communities
1. Climate change & impacts
2. Managing big data
3. Predicting extreme events
4. Prep for unpredictable events
5. Managing complex systems
6. Integrating disciplines
Ecosystem forecasts
Invasive species
Observing systems
Marine protected areas
Habitat restoration
Climate/weather impacts
Marine transportation
Height modernization
Coastal hazards
Natural Science
Social Science
Engineering & Design
New project
Core project
5. Cross-Cutting Research Foci
5a. Oil Spill Science
5a.1 - GL National Center of Expertise
5b. Integrated observing, science, and modeling
5b.1 - Biodiversity observation network
5b.2 - Systems approach to integration
5c. Data science and management
5c.1 - Bioinformatics for environmental omics
5c.2 - Data science
5c.3 - Data management
Number of proposed projects
18 12 26 19 18 12 18 22 22 22 31 23 32 16 23 25 25 34 35 11 24 12 8 26 14 4 18 41 18 22 11 34

Appendix 4 – Memoranda of Understanding

Appendix 5 – Letters of Support

Appendix 6 – References

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Appendix 7 – List of Collaborative Investigators

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4. Anthony Chappaz, Associate Professor, Geochemistry
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6. Tracy Galarowicz, Chairperson, Professor, Fisheries Ecology
7. Thomas Gehring, Professor, Mammalogy, Wildlife & Landsacpe Ecology
8. Marcello Graziano, Assistant Professor, Economic Modelling, Nat. Res. Mgmt,
9. Benjamin Heumann, Associate Professor, Remote Sensing/GIS,
10. Daria B. Kluver, Assistant Professor, Climatology
11. Deric R. Learman, Associate Professor, Geomicrobiology
12. Dale LeCaptain, Professor, Environmental Analytical Chemistry
13. Matthew E. Liesch, Associate Professor, Cultural and Historical Geography, Landscape Studies,
14. Andrew Mahon, Associate Professor, Molecular Ecology, Phylogeography
15. Scott McNaught, Professor, Zooplankton Ecology, Aquatic Food Webs
16. Anna K. Monfils, Associate Professor, Plant Systematics, Botany
17. Kevin Pangle, Associate Professor, Phenotypic Plasticity, Great Lakes Food Webs
18. Wendy Robertson, Assistant Professor, Hydrogeology
19. John I. Scheide, Associate Professor, Ion Regulation in Freshwater Mussels
20. Nancy E. Seefelt, Adjunct Professor, Avian Ecology
21. James Student, CELISA Director, Elemental and Isotopic Analysis
22. Yong Tian, Associate Professor, GIS, Land-Water Dynamics
23. Donald G. Uzarski, IGLR Director, CMUBS Director, Professor Limnology, Wetland Ecology
24. Daelyn Woolnough, Research Professor, Spatial, Conserv., & Aquatic Ecology
25. David Zanatta, Associate Professor, ConBio, Molecular Ecology
26. Tao Zheng, Associate Professor, Remote Sensing, Hydraulic Modeling

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5. Katie Edwards, Research Scientist, Natural Resources, Analytical Chemistry
6. Rod Getchell. Assistant Research Professor
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7. Charles Greene, Professor, Geology, Oceanography
8. Nelson Hairston, Professor, EEB, Limnology
9. Matt Hare, Associate Professor, Natural Resources, Genetics
10. Ian Hewson, Associate Professor, Microbiology, Aquatic Viruses

11. Robert Howarth, Professor, Ecology and Evolutionary Biology, Limnology, Oceanography
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4. Miguel Gomez, Associate Professor, Applied Economics & Management
5. Barbara Knuth, Professor, Dean, Senior Vice Provost
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5. Charlyn Partridge, Assistant Professor, Molecular Ecology
6. Rick Rediske, Professor, Ecotoxicology & Environ. Chem.
7. Carl Ruetz, Professor, Fisheries Biologist
8. Amy Russell, Associate Professor, Biodiversity & Genomics
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10. Alan Steinman, Professor & Director, Aquatic Ecology
11. Kevin Strychar, Professor, Climate Variation
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1. Neil Ashton, Assistant Professor, Aquaculture
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1. Syed Hashsham, Associate Professor, Molecular Genetics
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3. Phanikumar Mantha, Professor, Hydrologic Modeling
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2. Bruno Basso, Professor, Agricultural Systems Modeling
3. James Bence, Professor, Fisheries
4. Travis Brenden, Associate Professor, Fisheries
5. Erin Dreelin, Assistant Professor, Management & Outreach
6. David Hyndman, Professor, Hydroecology
7. Mike Jones, Professor, Fisheries
8. David Long, Professor, Biogeochemistry
9. Nathaniel Ostrom, Professor, Biogeochemistry
10. Peggy Ostrom, Professor, Biogeochemistry
11. Jiaquo Qi, Professor, Remote Sensing
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13. Joan Rose, Professor, Environmental Microbiology
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15. Michael Wagner, Associate Professor, Invasive Species

Social Sciences

1. Tom Dietz, Professor, Decision Making
2. Jiquan Chen, Professor, Geography
3. Ken Franks, Professor, Sociometrics
4. Eric Freedman, Professor, Environmental Communications
5. Cloé Garnache, Assistant Professor, Environmental Economics
6. Steven Gasteyer, Associate Professor, Sociology
7. Joseph Herriges, Professor, Environmental Economics
8. Frank Lupi, Professor, Environmental Economics
9. Aaron McCright, Professor, Sociology
10. David Poulsen, Professor, Environmental Communications
11. Scott Swinton, Professor, Agricultural Economics
12. Heather Triezenberg, Outreach Specialist
13. Jinhua Zhou, Professor, Environmental Economics

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1. Anne Carey, Professor, Hydrogeology & Geochemistry
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2. Justin Chaffin, Research Coordinator, Limnology
3. Suzanne Gray, Assistant Professor, Aquatic Physiological Ecology
4. Andrea Grottoli, Professor, Biogeochemistry & Paleoceanography
5. Margaret Kalcic, Associate Professor, Watershed modeling
6. Greg Labarge, Extension Specialist, Agriculture & Land Use
7. Jiyoung Lee, Associate Professor, Public Health
8. Stuart Ludsin, Associate Professor, Aquatic Ecology
9. Virginia Rich, Assistant Professor, Microbiologist
10. C. K. Shum, Professor, Remote Sensing, Themes

Social Sciences

1. Sathya Gopalakrishnan, Assistant Professor, Coupled Models of Human-Natural Systems
2. Timothy Haab, Professor, Human Decision-Making
3. Elena Irwin, Professor, Sustainability Modeling
4. Brent Sohngen, Professor, Environmental Economics
5. Robyn Wilson, Associate Professor, Risk Analysis & Decision Science

University of Michigan

Engineering & Design Sciences

1. Peter Adriaens, Professor, Clean Technology
2. Laura Balzano, Associate Professor, Computer Science
3. Aline Cotel, Associate Professor, Ecohydrology
4. Christiane Jablonowski, Professor, Climate modeling
5. Branko Kerkez, Assistant Professor, Intelligent Systems
6. Alison Steiner, Professor, Climate modeling
7. Ryan Eustice, Assoc. Professor, Robotics
8. Valeriy Ivanov, Hydrometeorology
9. Claire Pettersen, Assistant Professor, Climate science
10. Richard Rood, Professor, Climate impact engineering
11. Lutgarde Raskin, Professor, Environmental Engineering
12. Nancy Love, Professor, Environmental Biotechnology
13. Joan Nassauer, Professor, Landscape architecture
14. Dick Norton, Professor, Urban Planning

Natural Sciences

1. Dmitry Beletsky, Research Scientist, Hydrodynamics
2. Allen Burton, Professor, Ecotoxicology
3. Rao Chaganti, Assistant Research Scientist, Molecular ecology
4. Rose Cory, Professor, Environmental Chemistry
5. Vincent Denef, Associate Professor, Microbiology
6. Greg Dick, Professor, Microbiology
7. Meghan Duffy, Assoc. Professor, Ecology
8. Melissa Duhaime, Assistant Professor, Microbiology
9. Michael Fraker, Assistant Research Scientist, Limnology
10. Casey Godwin, Assistant Research Scientist, Limnology
11. Andrew Gronewold, Associate Professor, Hydrology
12. Jenan Kharbush, Assistant Professor, Biogeochemistry
13. Timothy James, Professor, Fungal Biology
14. Tom Johengen, Research Scientist, Limnology
15. Ayumi Manome-Fujisaki, Research Scientist, Physical Modeling
16. Paul Seelbach, Professor of Practice, Aquatic Ecology
17. Nathan Sheldon, Professor, Geology and Geochemistry

Social Sciences

1. Paige Fischer, Associate Professor, Social Science
2. Sarah Hughes, Assistant Professor, Water Policy & Equity
3. Maria Lemos, Professor, Climate variation & Behavior
4. Michael Moore, Professor, Environmental Economics
5. John O'Shea, Curator, Archeology
6. Jennifer Read, Director, Water Center
7. Noah Webster, Assistant Research Scientist, Social Science

University of Minnesota, Duluth

Natural Sciences

1. Jay Austin, Department Head and Professor of Physics, Circulation of Coastal Shelves, Estuaries & Large Lakes, Numerical Modeling
2. Elizabeth Minor-Austin, Department Head and Professor of Chemistry and Biochemistry Organic Biogeochemistry
3. Erik Brown, Interim AVC for Graduate Education & Research, Professor of Earth & Environmental Sciences, Sedimentary & Aquatic Geochemistry
4. Sergei Katsev, Associate Professor of Physics Sediment Early Diagenesis, Sediment/Water Column Coupling, Predictive and Exploratory Modeling
5. Sam Kelly, Assistant Professor, Physical Limnology and Oceanography, Internal Waves & Small-Scale Processes in Oceans & Large Lakes
6. Ted Ozersky, Associate Professor, Biology Elemental Cycling, Food Webs
7. Kathryn Schreiner, Assistant Professor of Chemistry & Biochemistry, Organic Geochemistry
8. Cody Sheik, Assistant Professor of Biology, Microbial Ecology of Large Lakes, Glaciated
9. Robert Sterner, Director of Large Lakes Observatory & Professor of Biology, Ecological Stoichiometry, Biological Limnology & Carbon:Nutrient Biogeochemistry
10. Byron Steinman, Assistant Professor of Earth & Environmental Sciences, Isotope Geochemistry, Ancient Pollution & Land Use in Lake/Catchment Systems, Climate Dynamics
11. Nigel Wattrus, Associate Professor of Earth & Environmental Sciences, Marine Geophysics

John Downing, Professor & Director of Minnesota Sea Grant, Limnology, Aquatic Ecology, Biogeochemistry, Fisheries, Lake Management & Restoration, Eutrophication, HABs, Groundwater, Biodiversity, Endangered Species, Carbon Cycling

University of Windsor

Engineering & Design Sciences

1. Brian Fryer, Professor Emeritus, Metal & Analytical Chemistry, Theme 3
2. Robin Gras, Associate Professor and CRC, School of Computer Science, Theme 2

Natural Sciences

1. Ken Drouillard, Professor, Contaminant Bioavailability
2. Aaron Fisk, Professor & Canada Res. Chair (CRC)
   Trophic and Movement Ecology
3. Joel Gagnon, Associate Professor, Inorganic Env. Chemistry & Geochemistry
4. Alice Grgicak-Mannion, Learning Specialist Geospatial Analysis
5. Doug Haffner, Professor & CRC, Aquatic Ecology
6. Daniel Heath, Professor, Conservation Genetics
7. Oliver Love, Associate Professor & CRC Evolutionary/Ecological Physiology, Behavioral Ecology
8. Hugh MacIsaac, Professor & CRC, Invasion Biology
9. Mike McKay, Professor, Microbiology
10. Scott Mundle, Assistant Professor, Contaminant/Nutrient Chemistry
11. Trevor Pitcher, Associate Professor, Evolutionary Ecology
12. Christina Semeniuk, Assistant Professor, Predictive Ecology
13. Chris Weisener, Professor, Biogeochemistry
14. Barb Zielinski, Professor, Olfaction in Fishes

Social Sciences

1. Amy Fitzgerald, Associate Professor, Sociology, Anthropology & Criminology
2. Wren Montgomery, Assistant Professor, Odette School of Business

University of Wisconsin-Milwaukee

Engineering & Design Sciences

1. Hector Bravo, Prof., Engineering & Applied Science, Hydrodynamics & Modeling
2. Woo Jin Chang, Asst. Prof., Engineering & Applied Science, Biological Engineering & Design
3. David Garman, Prof., Water Technology
4. Qian Liao, Assoc. Prof., Engineering & Applied Science, Hydrodynamics, Boundary Layer Processes
5. Matt Smith, Asst. Prof., Instrumentation & Sensor Development

Natural Sciences

1. Carmen Aquilar, Assoc. Scientist, Microbial Ecology, Phytoplankton
2. John Berges, Prof. Biological Sciences, Phytoplankton Ecology
3. Fred Binkowski, Senior Scientist, Fisheries & Aquaculture
4. Harvey Bootsma, Assoc. Prof., Limno., C & Nutrient Cycling, AIS
5. Michael Carvan, Prof., Ecotoxicology
6. Russell Cuhel, Senior Scientist, Long Time Series Monitoring of Lake Dynamics, Microbial Ecology
7. Tim Ehlinger, Prof., Restoration Ecology
8. Dong-Fang Deng, Senior Scientist, Fisheries, Aquaculture, Fish Nutrition
9. Tim Grundl, Prof.,Chemical Hydrogeology
10. Laodong Guo, Prof., Organic Biogeochemistry
11. John Janssen, Prof., Fisheries, Limnology

12. Jerry Kaster, Assoc. Prof., Invertebrate Ecology
13. Rebecca Klaper, Prof., Genomics, Pharmaceuticals, Emerging Contaminants
14. J. Val Klump, Prof. & Dean, Biogeochemistry, Hypoxia
15. Sandra McLellan, Prof., Microbio Eco., Water Quality, Genomics
16. Todd Miller, Assoc. Prof., HABs, Algal Toxins
17. Ryan Newton, Asst. Prof., Public Health, Microbial Ecology, Genomics & Sequence Analysis
18. Paul Roebber, Distinguished Prof., Atmospheric Science, Climate
19. Jhonatan Sepulveda Villet, Asst. Prof., Molecular Ecology, Aquaculture
20. Rudi Strickler, Distinguished Prof., Bio-Sci., Bio-Physics, Plankton Ecology
21. James Waples, Asst. Prof., Radiochemistry, Biogeochemistry
22. Shangping Xu, Assoc. Prof., Geosci., Contaminant Transport, Hydrogeo.
23. Erica Young, Assoc. Prof., Biological Sci., Phytoplankton Ecology

Social Sciences

1. Tracey Boyer, Assoc. Prof., Environmental Economics
2. Nancy Frank, Assoc. Prof., Architecture, Urban Planning & Policy
3. S. Scott Graham, Assoc. Prof., English, Science Communication
4. Jenny Kehl, Assoc. Prof., Water Policy
5. James Price, Assist. Prof., Environmental Economics
6. Itziar Lazkano, Asst. Prof., Economics, Environmental & Res. Issues