Assessment of GLISA's Contribution to Societal Impacts in the Great Lakes Region

Report Prepared for: Great Lakes Integrated Sciences and Assessments (GLISA)

January 9, 2021

Prepared by: Alison M. Meadow, Ph.D.

Meadow Evaluation | meadowevaluation@gmail.com

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Introduction

The Great Lakes Integrated Sciences and Assessment (GLISA), which has been in existence since 2010, is preparing to re-bid for another five years of program funding from the National Oceanic and Atmospheric Administration. In preparation for the re-bid, GLISA leaders sought to understand the impacts the program is having in the Great Lakes region and beyond. The mission of GLISA, and the broader Regional Integrated Sciences and Assessment (RISA) network, is to link climate science to decision making in ways that build the nation's capacity to prepare for and adapt to climate variability and change.

This assessment focuses on the ways in which GLISA is generating societal impacts – beneficial changes in policy, understanding, capacity, and partnerships – beyond the realm of academia. The first section of the assessment consists of six case studies of GLISA research projects that elucidate how GLISA researchers collaborate with regional decision makers and how and under what conditions GLISA research is used by decision makers. The second section focuses on the career impacts for students who have worked with GLISA as research assistants and how GLISA can and does contribute to innovations in graduate student science education. Both sections include recommendations about future monitoring, evaluation, and learning processes that can help GLISA plan, identify, and demonstrate its impact to funders, community partners, and the broader research community.

I. Societal Impacts

Societal impacts are the ways that research, and the process of conducting research, influences the world beyond the academic realm.

Impacts from research come in many different forms, both tangible and intangible. While often in the climate and environmental sciences, we aspire to long-term and large-scale impacts like measurable risk reduction or changes in ecosystem health, these kinds of impacts take substantial time to develop and are dependent on a wide range of variables, such as the ability of societal partners to enact new policies or practices (Bayley and Phipps 2019; Oliver et al. 2014). However, there are a range of nearer-term impact types that can tell us a lot about the successes and challenges of the kinds of collaborative research partnerships GLISA strives to maintain and the likelihood that research evidence will eventual contribute to large-scale changes in the future (Edwards and Meagher 2020). Societal impacts can be generated by both the research evidence and the process of undertaking the research – particularly in the kind of collaborative research processes used by GLISA in which societal partners are engaged in scoping, designing, and undertaking the research. Impact means that research evidence has moved into the realm of uptake and action; a research output is not an impact unless it can be linked to an action or other change beyond academia. An output, such as a report, tool, or academic paper can be an important vehicle for delivering research evidence to users. The process of engagement and interactions is also often key for mobilizing research into action.

Categories of Societal Impacts

Drawn from Edwards and Meagher (2019).

- **Instrumental impacts** – research (evidence and/or process) led to changes to plans, decisions, behaviors, practices, or policies
- **Conceptual impacts** –research contributed to changes in people's knowledge about or awareness of an issue
- **Capacity building impacts** –research contributed to enhancing the skills, expertise, or resources of an organization or group of people
- **Connectivity impacts** – research led to new or strengthened relationships, partnerships, or networks that endure after the project ends

In this report, I will also refer to three additional impact categories that can help describe the influence of a research project or research findings:

- **Culture/attitude impact** – the research has changed the researcher's attitude toward engagement/collaboration with societal partners and the concept of societal impacts
- **Academic impact** – can include standard metrics such as citation counts and impact factor as well as evidence that colleagues use the research outputs in their own work (an indicator of credibility)
- **Socio-ecological impact** – research contributes to beneficial social and/or ecological changes after its application to plans, decisions, behaviors, practices, or policies; often a long-term impact.

There is no hierarchy to these categories. They all are valuable outcomes for a project or program to generate. They do, however, influence each other in that connectivity and capacity impacts, which can be thought of as emerging from the process of research, may make conceptual and instrumental impacts more likely. Additionally, instrumental impacts are more likely to emerge when there have been conceptual impacts (Choo 2006; Oh and Rich 1996). Instrumental impacts, like their longer-term counterparts socio-environmental impacts, may take longer to become evident (Penfield et al. 2014), therefore, it is important to collect evidence of connectivity, capacity, and conceptual impacts as indicators of other future changes.

Societal impacts can and do emerge from multiple pathways (Muhonen, Benneworth, and Olmos-Peñuela 2020) – there is no one standard method for moving research to action. Generating societal impacts requires that the research be context-specific and responsive to the needs and interests of the societal partners (Mach et al. 2020; Norström et al. 2020). Although it is possible to have impact through an indirect connection such as a research output being taken up by a decision-making body without their direct engagement in the research process, the more effective and efficient pathway from research to action is through direct and ongoing engagement between researchers and societal partners, "productive interactions" (Spaapen and van Drooge 2011; Muhonen, Benneworth, and Olmos-Peñuela 2020). Engagement processes are often pivotal to the achievement of societal impacts. The extent to which and ways in which researchers and societal partners collaborate has been shown to influence how and under what

conditions research products are adopted and used by decision makers (Spaapen and van Drooge 2011; Association of Public and Land-Grant Universities 2019; Reed and Meagher 2019). This engaged mode of research is the approach GLISA uses most often. Research modes that rely on direct engagement between researchers and societal partners to share and build upon each other's knowledge include, but are not limited to, co-production of knowledge (Jasanoff and Wynne 1998; Lemos and Morehouse 2005), transdisciplinary research (Pohl 2008), engaged scholarship (Beaulieu, Breton, and Brousselle 2018), or contextualized research (Jong et al. 2020).

Societal impacts can be demonstrated in a number of ways including: references to the research in agency documents (such as plans, policies, or position statements); documented responses from research participants such as surveys and interviews during or after the project; informal communications between societal partners and researchers such as follow-up questions or descriptions of how partners are engaging with the research; or invitations to participate in future projects.

In this assessment, I relied on impact data already collected by GLISA in annual reports as well as new interviews with both researchers and societal partners from 5 sample cases[1]. I selected the sample cases in such a way as to include projects from the three main sectors of GLISA's work: urban communities, tribal communities, and agricultural production. Within each category, I selected projects randomly (using a random number generator), but also conferred with GLISA core staff to ensure that enough data was available on each project to complete the analysis.

This assessment was done retrospectively, which poses certain challenges. First, participant recall of engagement processes, use of evidence, etc. is weaker than if we were collecting data concurrently with project activities (Wiek et al. 2014). Second, the projects were not designed or implemented with the goal of collecting the kind of impact data presented here, which means that impacts may not have been recognized or reported with sufficient evidence to corroborate the impact.

Overview of GLISA

GLISA aims to support a sustainable future for the Great Lakes region by generating cutting-edge climate science and social science in collaboration with decision makers and communities in the Great Lakes. The GLISA theory-of-change rests on the concept of co-production of knowledge in which scientists and societal partners co-design and co-generate the research necessary to inform decision making. In short, GLISA operates on the (well-founded) theory that its basic research, mediated through its collaborations with societal partners, makes tangible contributions to the region's capacity to plan for a more sustainable future.

In 2015, GLISA entered its second phase of funding (2015 – 2020). In this phase, the GLISA team identified seven research and program goals intended to help it fulfil its mission in the region:

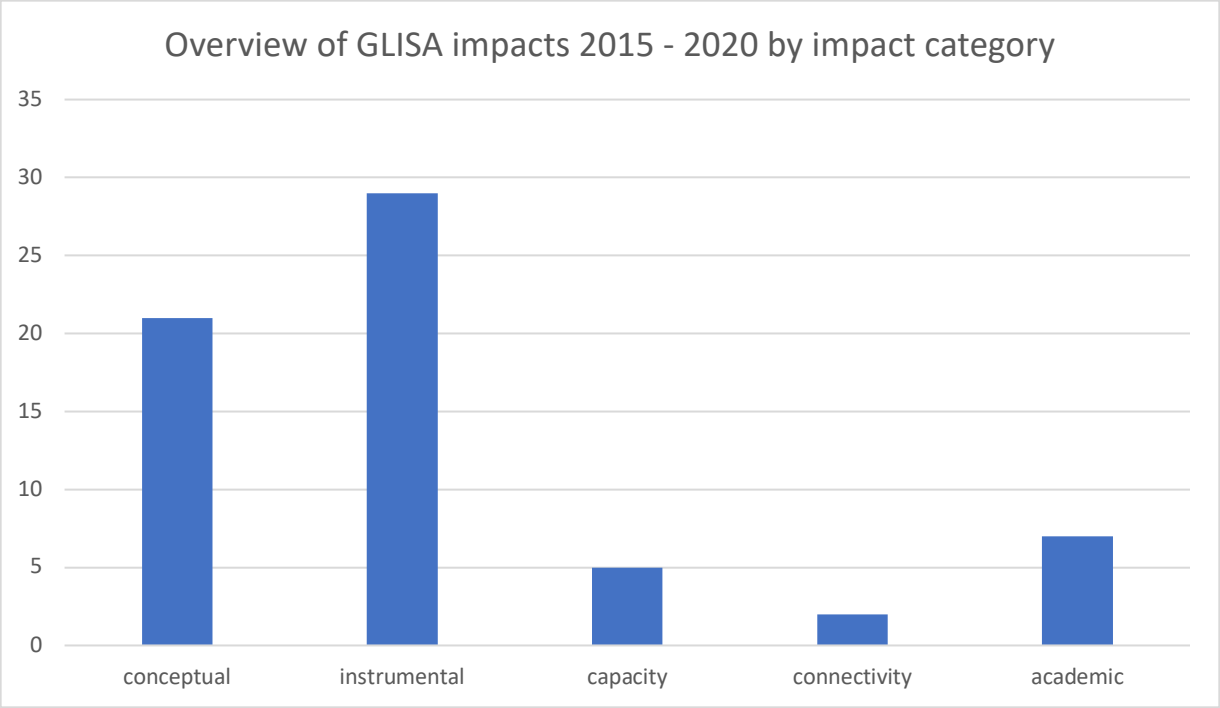
[1] The *Future Scenarios for Lake Ontario* project was a small grant project funded toward the end of the previous GLISA phase but selected for this assessment because it represented a partnership with an important regional organization, New York Sea Grant.

1. To form, tailor, and maintain and ensemble of historical data resources and model projections and a coupled set of lake and inland observations for the region
2. To develop new and adapt existing tools and information to support decision making in areas related to lake levels and ice cover, freezing rain and agriculture related needs.
3. Develop a "user's guide" for decision makers for considering use of CMIP3 and/or CMIP5 and that compares the two models
4. To understand how climate information disseminates through networks and boundary chains and with what outcomes
5. To understand how different means of stakeholder engagement influence climate information usability
6. To deepen our collaborations with established partners such as Great Lakes cities in support of adaptation, and actively pursue our sustained assessment effort
7. Explore new avenues of research and application in areas such as climate adaptation governance in indigenous communities and valuation of climate information for the agricultural sector.

In support of these goals, GLISA developed 43 separate research and/or engagement projects. These projects were funded through the core grants from NOAA-RISA, through external funding sources, or a combination of the two. The program also provided funding for 11 grants through its small grants program.

Summary of GLISA Impacts in Phase II

Through a course analysis of available data from GLISA's last five annual reports, I compiled an overview of the kinds of impacts GLISA has had in the region. For the purposes of this assessment, I included the academic impact category to capture examples of GLISA work being used by academic colleagues to further their own research efforts.



Based on this overview, GLISA has an excellent track record of moving research into use in the Great Lakes region. It is important to acknowledge the likelihood that a reporting bias has affected this analysis. GLISA has focused on reporting use of its research (i.e. instrumental impacts) because of funder requirements. This bias does not mean that the instrumental impacts didn't occur – but it does mean that other types of impacts have not been traced or reported as consistently and are, therefore, likely underrepresented here.

Examples of the 29 instrumental impacts generated through GLISA research efforts include a number of cities using GLISA-generated climate data to support their adaptation plans or to contribute to other decisions such as green infrastructure planning; several state and federal parks using GLISA climate data in their planning; and tribes integrating climate data into climate change, hazard mitigation, and infrastructure plans. Several of these examples will be addressed in greater detail in the case studies below. GLISA is also helping to increase understanding and awareness of climate change and engagement practices in the region, as evidenced by 21 examples of conceptual impacts. These include use of GLISA climate information in discussions about adaptation planning (i.e. organization/government has not yet reached a formal planning phase); reference to GLISA climate data in congressional hearings; and use of GLISA's ensemble models and CMIP5 guidance to help agencies understand the current state of climate science.

Examples of capacity building and enduring connectivity are far fewer in this analysis, also due to the emphasis on "use" impacts discussed above. Additional information about capacity building and connectivity will likely emerge from the analysis of the small grants program, which are intended to test GLISA's boundary chain model of engagement. The examples that are available include GLISA's research being used in several classrooms in the region, contributing

to building the capacity of the next generation of decision makers. Several societal partners also described the ways in which the process of engaging with GLISA has helped build their capacity to communicate more effectively with the public and media about climate change impacts. The clearest example of enduring connectivity is the existence of GLCAN, which GLISA supports through funding and administration. GLCAN brings municipal, county, and state staff together on a regular basis to discuss sustainability and climate issues affecting the Great Lakes. One participant in the stormwater vulnerability assessment project (highlighted below) specifically named her connection to GLCAN as a key outcome of her participation in the research project.

Case Studies

The following case studies are intended to highlight the impacts generated by a sub-set of GLISA projects. To the extent possible the cases also discuss the engagement process. As noted above, recall of specific details of engagement and communication can be weak if this information is not collected in-the-moment. However, all interview participants made every effort to provide those details.

In a recent analysis of the UK's research assessment tool, the Research Excellence Framework, reviewers identified 3,709 unique impact pathways among the 6,647 impact case studies submitted to the 2014 assessment (Bayley and Phipps 2019). The diversity of pathways is confirmed by other recent analysis in which researchers distilled 12 broad pathway types from an analysis of 60 cases (Muhonen, Benneworth, and Olmos-Peñuela 2020). Although there are multiple ways that academic research can, and does, generate societal impacts, the most effective pathways include direct interactions between researchers and society, such as the kind practiced within GLISA. The five case studies presented here reinforce the multiple pathways theory because they demonstrate how different approaches to engagement and contextualizing research have all generated impacts.

Future Scenarios for the Lake Ontario Watershed

The binational Lakewide Action and Management Plan (LAMP) process required that climate change be included in watershed planning for lake quality in the Great Lakes. This project began as an effort to use climate scenarios to inform the LAMP for Lake Ontario. The original goal was to elicit input from scientists, managers, and community members about potential "win-win" policies that would be effective under four climate and demographic scenarios (wetter or drier; population growth or loss). The focus shifted over the course of the project to more broadly address climate and sustainability issues in the Lake Ontario watershed through the inclusion of a cross-section of regional stakeholders.

The Lake Ontario Scenarios project built on a prior workshop (Workshop I), held in 2012 by New York Sea Grant (NYSG), in which four plausible climate and demographic scenarios, using the axes wetter-drier and population growth-loss, for the Lake Ontario watershed were developed.

The GLISA small grant program provided funding to NYSG to hold three additional workshops - Workshop II (May 2015) and Workshops III A and B (November 2015) - with the goal of identifying strategies that would be effective for the region no matter which climate/growth scenario came to pass. GLISA's role in the project was to compile information about the four scenarios, create a handout for workshop participants, and contribute expertise in scenario planning. Because the scenarios had been developed prior to awarding of the small grant, there was no new science to produce. Laura Briley from GLISA, who brought her experience with scenario planning to the project, attended and helped to facilitate Workshop II. Workshop II was a 2-day event and included representatives from GLISA, the Northeast Regional Climate Center, US Geological Survey, Cornell University, and the NY State Lake Ontario LAMP coordinator. Participants used the four scenarios to draft policy recommendations for the future of the Lake Ontario watershed. Workshops III A and B (November 2015) were evening workshops with community members, environmental groups, anglers, boaters, local legislators, and local environmental agencies. Participants rotated through 5 stations where they had a chance to discuss the draft actions from Workshop II, add actions, modify actions, and vote on the best recommendation at each station.

The output from this project was a report summarizing the recommendations developed through the workshops. The recommendations fell into five sectors: water resource management, infrastructure, land use planning, ecosystem management, water-dependent businesses.

The NYSG team noted a number of lessons-learned about how to make scenario planning workshops more effective for participants. For example, they noted that although their initial goal was to generate recommendations for the LAMP and Watershed Plans, because of the diversity of participants (members of the public, local government officials and employees) many of the recommendations were not those typically associated with the LAMP process. They also noted that the large geographic scale of their work may have limited its immediate applicability (outside of the LAMP process). However, the researchers noted that the recommendations were still relevant to the LAMP as well as capturing the needs of residents and local government.

The most significant impact of this project appears to be a change in practice - the adoption of scenario planning as a technique – by NYSG and a workshop participant from NY State government. Riobart Breen, who participated in Workshop II provided two examples of NY State agencies (with which he is associated) applying scenario planning because of his experiences in the workshop. The NY Department of State integrated scenario planning into its Lake Ontario resilience planning initiative, Coastal Lakeshore Economy and Resiliency (CLEAR). The NY Department of Environmental Conservation plans to use scenario planning approaches with local communities that will be developing climate adaptation and resilience plans (work slowed due to the pandemic). NYSG has adopted the approach for use in its internal decision making.

Breen summarized the impact of the project in his opinion, "The Lake Ontario scenarios planning project did not attract enough diverse public participation to make the process and results valid for directly developing official state policy, but I am not sure it was designed to do that. It clearly hooked me, though, and I am now committed to expanding scenario planning methodologies for use in climate change planning and policy making."

The scenarios may also have contributed to capacity-building through their use in several higher education courses. PI Katherine Bunting-Howarth shared the scenarios in a guest lecture to an architecture class. Workshop participant Breen used them in a course he taught on climate adaptation and resilience policy.

This project was challenging to evaluate because of the time lag between activities and my evaluation efforts. It was not easy to identify or follow-up with workshop participants, with the notable exception of Breen from NY Department of Environmental Conservation. GLISA's role in this project was quite limited. The climate and demographic scenarios had been developed prior to GLISA's involvement – so there was no new climate data to contribute. The small funding amount makes it harder for researchers to allocate time and resources to follow-up and evaluation. However, GLISA's new system for evaluating the small grants program should alleviate that issue in the future.

The Lake Ontario Scenarios project effectively built upon previous work and engage a broad cross-section of the target region in the process of scenario planning. Although the shift in focus from climate change and water quality issues, which would have fed directly into the LAMP, means that there is little evidence of direct use of the research findings, the PI and one workshop participant provided several examples of how the scenario planning process has influenced a change in practice (adoption of the technique of scenario planning) in several regional agencies.

Fort Custer Training Center Scenario Planning

Department of Defense installations with significant natural resources are required to develop and maintain Integrated Natural Resource Management Plans (INRMP) that guide managers as to how to minimize impacts to sensitive natural resources and to maintain the land, so it is suitable for military training. Fort Custer Training Center (FCTC), a National Guard training base in Battle Creek, Michigan has had an INRMP in place since 2001 to protect the land and species within its 7,570-acre facility. The FCTC has populations of 10 state-listed wildlife species and 14 state-listed plant species. In addition, FCTC provides potential habitat for 8 federally listed wildlife species with known populations nearby, although no individuals have been documented on FCTC, according to the 2020 INRMP (Michigan Department of Military and Veterans Affairs 2020).

Michele Richards, the Natural Resources Manager at FCTC, approached GLISA with a request for help integrating climate change information into the INRMP. Michele brought years of experience managing FCTC's natural resources to the project, as well as her own knowledge about climate change and impacts in the region. In addition to her work in Michigan, Michele consults with other National Guard stations around the country about natural resource management and climate change. GLISA worked with Richards on this project to develop climate information and future scenarios for FCTC based on four key management concerns: fire, invasive species control, High Quality Natural Areas/habitat, and water and soil resources. The topics were identified by Michele as priorities for FCTC.

To effectively integrate the climate information into the INRMP, FCTC and GLISA designed a workshop to bring together relevant stakeholders to develop climate scenarios for decision making at FCTC. Participants included representatives from other natural resource planning agencies, with whom FCTC must collaborate on its INRMP. Laura Briley, from GLISA, and Richards had a number of discussions early on to determine the implications of climatic changes on these four sectors to prepare relevant climate information for the workshop. The summary information GLISA prepared for the workshop included historical climate data, current trends, future projections, and a brief overview of likely impacts. GLISA also developed a scenario planning workbook to guide group discussions and assessments by FCTC at the workshop. The scenario planning process built on GLISA's experience doing scenario planning with the National Park Service. Briley noted that it was important that Richards take the lead in presenting at the workshop because of her established relationship with participants – she is a trusted and authoritative figure. The workshop focused on the four key management concerns listed above. At the workshop, participants broke into four groups, each assigned to one of the key management concerns, identified key management decisions for their topic, then assessed how weather and climate events as well as climate change might affect those management decisions. Each group developed a list of management recommendations and ideas through their discussions.

GLISA's work with FCTC yielded a number of positive impacts. First, based on a survey administered by Briley at the workshop, participants noted that they gained a better understanding of scenario planning and became more familiar with the data on climate trends. They also responded that the information presented in the workshop would inform their future

planning and actions. Second, the climate summary was included in the FCTC INRMP and discussion of climate impacts on natural resources are integrated throughout the document. Richards noted that, because of the collaborations between FCTC and other natural resource management agencies and organizations in the region, the climate data is being shared and circulated in the region. She provided a specific example of her work with Southwest Michigan Land Conservancy to create and maintain wildlife corridors that will be resilient in the face of climate change. The FCTC INRMP was recognized with an award from the Department of Defense for its efforts to promote the conservation of natural resources, including the identification, protection and restoration of biological resources and habitats; sound long-term management and use of the land and its resources; support of the military readiness mission; and the promotion of a conservation ethic. FCTC was commended for being the first installation to integrate a customized climate adaptation plan into its INRMP and operations. Finally, beyond its direct application for FCTC, the scenario planning workshop developed by GLISA has been adapted, by a group of graduate students from University of Michigan, for use in the Seychelles.

The collaboration between GLISA and FCTC exhibits several elements that have been shown to support impacts such as the use of research findings in policy and practice, as occurred when FCTC integrated climate change considerations into their INRMP. GLISA and FCTC, through Richards, had an existing relationship that could be characterized as a "mature partnership" because of its length (10+ years) and level of trust (Kothari et al. 2011). Richards had been participating in GLISA events for a number of years and had on occasion acted as a friendly reviewer for GLISA documents. She knew and trusted the organization before approaching them about this project. The research question came from the practitioner partner (FCTC) and was tied to an immediate (or near-term) need for information to be applied in a specific plan. The two partners – GLISA and FCTC – then interacted and iterated to refine the questions to be most useful to FCTC. GLISA data outputs were presented at "decision scale" for FCTC – they covered the key areas over which FCTC is responsible. Richards is a proactive planner when it comes to climate issues, she was described by her GLISA partner as an "adaptation champion," meaning that she was capable and willing to engage and act on climate issues as well as champion the cause within her agency. Finally, several context factors contributed to the success of this project. First, the 2018 DOD guidance on including climate change in INRMPs created both space and incentive for FCTC to pursue climate planning. Second, many Michigan natural resource agencies are also pro-active about climate change in their planning; because FCTC is required to collaborate with surrounding agencies, FCTC had significant support for its decision to integrate consideration of climate impacts into its formal planning process.

Lac du Flambeau Band of Lake Superior Ojibwe Climate Adaptation Planning

Members of the Lac du Flambeau Band of Lake Superior Ojibwe have been observing changes in the climate and seasons for a number of years. Community members noted that there is less ice in the winter and that summer temperatures were higher. They are concerned that changes in climate are affecting the phenological cycle of plants, which in turn disrupts traditional signals for the start of hunting and fishing seasons.

Lac du Flambeau's resilience planning process began with a former employee, who led the natural resources team. The team took their concerns to the Tribal Council, who directed the team to find funding and initiate resilience planning. The Tribe received funds from Department of Energy to undertake the planning process. The Tribe's Resilience Initiative includes four components: an energy reduction plan, updates to the Multi-Hazard Mitigation Plan (MHMP), a vulnerability assessment, and a climate adaptation plan. The Tribe sought community engagement in the planning process with the goals of long-term resilience despite the climatic changes, protection of key species, and a way to plan development with future conditions in mind.

Lac du Flambeau contracted with Adaptation International, a consulting firm with experience crafting climate change adaptation plans with tribes. Adaptation International contracted with GLISA as well as several other organizations to complete the process. GLISA provided all the climate analysis, including observed climate data and climate model projections using the RCP 8.5, or "business as usual" scenario. GLISA climatologist Omar Gates worked with the Tribal Climate Resilience Project (TCRP) team to identify the appropriate geospatial scale of analysis. Although it is common to use established climate divisions for such analysis, in this case it was important that the project boundaries be meaningful to the tribe, so GLISA created custom analyses that incorporated watersheds within 50 miles of the reservation boundaries in order to include key hunting and fishing territories. Ensuring that the analysis boundaries matched a meaningful geospatial area was important to making the climate information useful, according to Sascha Petersen from Adaptation International. Gates met with the TCRP in person twice and presented the climate data to the Tribal Council. Gates reflected that the process of discussing priorities and questions with the TCRP was important because it helped him understand how climate change fit into community concerns and how he could present the data most effectively. Eric Chapman, Lac du Flambeau's Emergency Management Coordinator as well as a tribal council member, explained that the planning process and opportunities to interact with Gates helped him better understand and trust the climate data being used in the plan. Gates noted that he regretted that other work commitments kept him from staying engaged in the planning process throughout the project.

GLISA's climate analysis has been directly used in three components of the Resilience Initiative. First, the climate analysis was included in adaptation plan, which was approved by Tribal Council in September 2020. The plan focused on natural resources, community and public health, and infrastructure. Second, the climate data was used in revisions to the Tribe's MHMP. The MHMP included as hazards: climate change impacts on plants and animals, particularly species loss because such losses affect culture and history; increased risk of flooding; increased risk of freezing rain and related winter storm impacts; and increased risk of extreme heat. The

climate analysis was also used within the vulnerability assessment process to help determine how climate change is likely to affect culturally significant species. This analysis will be used to update the tribe's Integrated Natural Resources Management Plan. Chapman noted that in his role on the tribe's Land Use Planning committee, he intends to use the climate data to help inform his recommendations on future development on reservation lands. Chapman listed several other programs that are using the climate adaptation plan and climate information in their work now, including the Wild Rice Program, the Conservation Law Enforcement department, the Planning and Development department, and in building maintenance.

Brian Gauthier (Lac du Flambeau Tribal Community Development Educator - University of Wisconsin Madison Extension), another member of the TCRP along with Chapman, echoes Chapman's statement that they would work with GLISA again in the future, calling GLISA a "top-notch organization." GLISA's "expertise and knowledge base was key to this effort," according to Gauthier.

In addition to using the climate data in plans and policies, the process of engaging in the planning efforts has increased the Tribe's capacity when it comes to communicating about climate change. Petersen reflected, "GLISA helped the Tribe be confident talking about climate change," by providing the data and clear explanations about how it was developed. After completing the planning process, Chapman spoke about the planning process at the National Adaptation Forum. As part of new funding from the Bureau of Indian Affairs tied to the vulnerability assessment, Lac du Flambeau will host a national conference about tribal climate adaptation planning.

This case exhibits several characteristics that have contributed to the instrumental, conceptual, and capacity-building impacts described above. GLISA's willingness and ability to provide climate data at a meaningful decision scale for Lac du Flambeau made the data easier to understand and use. A key part of the process of determining the geospatial extent of the data was that Gates took time to learn from his partners at Lac du Flambeau and understand their priorities and questions. The representatives from Lac du Flambeau are a well-organized, motivated group of people committed to the planning process and taking appropriate actions. The TCRP team had the ability to directly apply the climate data in their planning work. Finally, the collaboration with Adaptation International meant that there was additional capacity for this project – expertise in how to use climate data in adaptation plans and, through the inclusion of a disaster mitigation firm, expertise in how to integrate climate risk into a Multi-Hazard Mitigation Plan.

Co-producing Climate Knowledge and Sustained Engagement in the Great Lakes in Support of Stormwater Management Adaptation

An example of the ways that GLISA's work builds on itself and expands networks comes from a series of projects that started with developing a vulnerability assessment template in 2017. The *City Climatologies for Vulnerability Assessment Templates* project was funded by the Urban Sustainability Directors' Network with a goal of producing a template that cities could use to learn to mainstream climate and socio-economic considerations into various types of systems planning. The project was a partnership between GLISA, Huron River Watershed Council (Rebecca Esselman), and independent consultant Missy Stults. The project began with five partner cities: Ann Arbor, Dearborn, Evanston, Indianapolis, and Cleveland. In an effort to test the template, the PIs again partnered with GLISA, using funding from the NOAA Sectoral Applications Research Program (SARP) program to develop the *Co-producing Climate Knowledge and Sustained Engagement in the Great Lakes in Support of Stormwater Management Adaptation* project. The focus of the template and testing narrowed to stormwater vulnerability as a way to make the project more tractable. GLISA recruited 12 cities in the region to participate. GLISA added a component to the pilot test – a comparison of three different methods of delivery of the information. Cities were divided into three groups: those that received the stormwater vulnerability template and training in person, those that received it through a live webinar, and those that received all the information in pre-recorded videos. GLISA continues to evaluate the efficacy of the three delivery methods and that question is not included in this impact assessment.

As part of the stormwater system vulnerability assessment process, each of the 12 cities received the same training materials, which included city-specific climate summaries (built upon engagements with the five cities involved in the original 2017 project), climate and socioeconomic data delivered through the Neighborhoods at Risk tool developed by project partner Headwaters Economics; and a workbook for cities to use to walk themselves through the assessment process. After the instruction provided by Stults and Esselman, each city team worked through the workbook and completed the template, which fed into a stormwater system vulnerability report for their city. The GLISA team conducted follow-up interviews with representatives from four of the cities. Given the timing of the conclusion of the Stormwater Vulnerability project, just as the coronavirus pandemic was taking hold in early 2020, all researchers and participants acknowledged that progress was slowed as cities turned their attention to pandemic response. In some cases, city employees may have been re-assigned or laid-off and were unreachable.

I was able to speak with representatives from three cities for an additional follow-up – Toledo, OH; Ferndale, MI; and Madison, WI. Two of the cities received in-person training and one received the pre-recorded training videos. All three representatives found the training workshop or videos informative and accessible. All three had some form of follow-up with Stults or Esselman after the workshop –either by email or phone – to get clarification on a task in the workbook or discuss city-specific data questions. They all found Stults and Esselman to be helpful and approachable and appreciated being able to ask follow-up questions. A complicating factor in this project was that both Stults and Esselman transitioned to new jobs during the project. One city partner commented that it became harder to reach the PIs over the course of the

project. The situation – and challenges it posed for the project and partners – was acknowledged by both Stults and Jenna Jorns of GLISA. It is an unusual situation to have both PIs manage job transitions in such a relatively short time, so it unlikely GLISA will have to manage this particular situation again, but it is worth considering how PI turnover can be planned for in the future to minimize disruption to the project.

The stormwater vulnerability template proved useful to each of the three cities, each in slightly different ways. Given the relatively short time since this project concluded and the effects of a global pandemic, identifying instrumental impacts was less likely. However, the representative from Toledo noted that the climate data provided in the project was used to support an environmental justice grant the city received in 2020. In Ferndale, the city's Environmental Sustainability Planner explained that, partly due to the experience of the stormwater assessment, the city was planning to include a green infrastructure element in a roadway resurfacing project. That project is on hold because of the pandemic, however.

A common theme in all three cities was the value of the *process* of completing the assessment, which generated a number of conceptual impacts in the three cities. In Madison, the Sustainability Manager noted that completing the assessment workbook gave her an opportunity to capture the implicit institutional knowledge of the head of the Stormwater department – something that had not previously been done. She found it valuable to know that knowledge could be shared and referred to even if the Stormwater director wasn't present. This experience was shared by the Stormwater representative from Toledo who described the ways in which city departments discussed their priorities and learned about each other's work during the course of the workshop. A more specific impact from Toledo is that working through the assessment helped city staff realize that they were missing some key data about their stormwater system and initiated conversations about updating their management practices to help them avoid data gaps in the future. Similarly, the process of completing the assessment provided an opportunity for Ferndale engineers to consider the role of climate change in their work, according to the Sustainability Planner this is a conversation that had not happened in depth prior to this project.

In both Madison and Ferndale, the stormwater assessment process helped the interviewees build capacity in communicating about flood risk to the public. In both cases, they described feeling more confident in discussing flooding, which was particularly important because both cities experienced severe flooding recently (2018 and 2020 respectively) and were receiving many questions from residents.

The project generated new connections as well. One type of connection was within a city – a type of connectivity not addressed in the standard definitions, but one that is important to city staff. In Madison, the Sustainability Manager described how the process of completing the stormwater assessment helped her create new connections between herself and the Stormwater department by providing the opportunity to work together. The project also grew connections outside of individual cities by linking the Sustainability Manager in Madison with the Great Lakes Climate Adaptation Network, a connection she has maintained post-project.

Both Madison and Ferndale have specific plans for using the stormwater assessment data in the near future. In Madison, the city expects to start an equity analysis for future stormwater projects

and will use the socio-economic data provided in the assessment to support that work. They also hope to resume (post-pandemic) a city-wide resiliency assessment project which will be led by WICCI (Wisconsin Initiative on Climate Change Impacts). Ferndale is anticipating future grants for additional green infrastructure work in its roadways and Complete Streets projects, which will be supported by the findings from the stormwater assessment.

All three cities also provided ideas for future work with GLISA. One common theme was wanting at least one more interaction related to the stormwater assessment, such as a webinar or report summarizing the experiences of all the cities that participated. Such information sharing could help spur collaborations or the kind of friendly competition between regional cities that can lead to innovation (as suggested in the 2016 GLISA annual report). Another point of engagement could be to have GLISA representatives present climate change information to city councils, which could help bring additional credibility to the issue because of GLISA's reputation in the region. In terms of topics for future collaboration, heat (Madison) and mobility/waterfront planning (Toledo) are two topics that will be on city's agendas in the near future.

The vulnerability assessment project has now evolved into new projects on the Gulf Coast, *Making Gulf Communities More Resilient* (funded by the National Academy of Sciences Engineering, and Medicine's Gulf Research Program) in collaboration with Southern Climate Impacts Planning Program (SCIPP).

Several characteristics of this project have contributed to its demonstration of impacts, even at this early time-step. The PIs had unique roles as both researchers and practitioners, which gave them crucial insights into and context knowledge about the needs and capacities of municipal government decision makers. This context knowledge and first-hand experience helped them to tailor the climate data and create a workbook tool usable by municipal governments. The project also built upon and expanded existing connections. First, it utilized the existing GLCAN network to invite cities to participate, it expanded GLCAN by inviting new participants, and the new iteration of the project on the Gulf Coast has strengthened ties within the RISA community between GLISA and SCIPP.

Economics of Wind Machine-Based Frost Control for Tree Fruit Production in the Great Lakes Region

A project that is expected to expand beginning in 2021 provides an example of the way in which GLISA's work in the agricultural sector effectively uses the context knowledge of GLISA researchers to respond to the changing needs of the agricultural community.

The *Economics of Wind Machine-Based Frost Control for Tree Fruit Production in the Great Lakes Region* project has its roots in a 2012 freeze event that devastated the Michigan specialty crop industry. The event, in which an early heatwave in March that caused an early bloom was followed by a return to seasonal temperatures and several freeze events, caused an almost complete loss of the apple crop. The apple industry organization The Michigan Apple Committee, estimated that only 3 million bushels survived, compared to a usual harvest of 20-23 million bushels. Economic loss estimates reached nearly $1 billion.

GLISA PI Jeff Andresen has been researching the climatic changes that are bringing earlier warm temperatures to the region without eliminating the risk of freeze events. Farmers have been concerned about whether events like 2012 will repeat and what they can do to protect their livelihoods. One option is the use of wind machines to reduce the impact of freeze events. The wind machines can raise the temperature in an orchard by a crucial 2 – 4° F. Michigan farmers have already started to use this technology. However, the wind machines are expensive – approximately $30,000 per machine, which covers about 10 – 12 acres of orchard. Andresen began a cost-benefit analysis of the wind machines in collaboration with Roy Black, an agricultural economist at Michigan State University, that would use climate projections along with data on the costs to purchase and run the machines to estimate their benefit to Michigan apple growers.

Andresen explained that he is motivated to provide this information to farmers because these machines represent a very large investment for farmers. He hopes the project helps growers better quantify their current weather and climate-related production risks and help inform decisions regarding capital investment. He wants to provide information to allow growers to make informed decisions about use of these wind machines. "Any way we can help," he said.

Unfortunately. Dr. Black passed away in the summer of 2020. Andresen plans to work with another MSU agricultural economist, Matt Gammans, to complete the work he and Black started. Andresen has already completed the climate analysis, which simulates frost events on a daily basis with a temperature-based model to estimate the frequency and severity of cold damage for a given location. The next steps are to use literature-based assumptions about the expected effectiveness of the frost protection technology and develop a series of simulated years with estimated crop yields. Then they will compare the difference in net revenues above the costs considered between management approaches including none, wind machine frost protection, crop yield insurance, and the combination of wind machine frost protection and crop insurance.

Andresen works closely with Cooperative Extension agents to connect his research with the agricultural community. He notes that they are willing collaborators in these efforts and that they "open doors you never would otherwise." He has already presented his climate analysis about

early spring and the persistence of freeze events to growers at several events organized by Extension. He has also had informal conversations with growers about the costs of using the wind machines and how they decide when to use them, which will help inform the economic analysis. Once the economic analysis is complete, he plans to have more discussions with growers to "ground-truth" the analysis, ensuring that the data inputs for the economic analysis accurately reflects their experiences.

This project builds upon strong relationships between Andresen and Cooperative Extension and the Michigan agricultural industry in general as well as his own deep context knowledge about the agricultural industry, which helped him identify questions of particular salience to the industry. By collaborating with Extension, Andresen has assured that he is working through trusted channels to reach growers. Andresen selected a research question he knew was of primary importance to growers – frost is a significant concern for Michigan specialty crops. His ultimate motivation is to help growers make informed decisions about a tool that has potential to protect their livelihood, but also comes with significant financial risks.

As this project develops, it will be important to follow up on how growers receive (accessibility) and perceive (changes in understanding) the research findings as well as speak with growers to determine whether the research findings contribute to their decisions about use/non-use of the wind machines or other changes in management practices.

The Great Lakes Ensemble Project

The Great Lakes Ensemble (GLE) project aims to provide the highest quality climate data and information to stakeholders in the Great Lakes region by first, evaluating climate models based on their ability to accurately capture Great Lakes dynamics and second, developing guidance for model users about how to evaluate model accuracy. The project is particularly important to GLISA because of GLISA's role in providing tailored climate data for use by GL stakeholders. As an organization, GLISA is dedicated to providing the most credible, usable science possible and, therefore, wants to use the climate models that are most robust for the region. A primary user of the GLE will be GLISA researchers themselves.

The GLE project team has investigated the representation of the Great Lakes in 54 CMIP5 models and found that only 8 include or accurately capture at least one Great Lake. In addition, the team has evaluated several dynamically downscaled Great Lakes projections for inclusion in the ensemble. The project team works with both a science advisory committee and a stakeholder working group to ensure that their scientific analyses are sound and that project outputs will be accessible and usable for practitioners in the region.

The complexity of the analyses required to determine the accuracy of climate models when it comes to simulating the Great Lakes means this project has taken longer than anticipated to complete. Although examples of direct use and impacts are difficult to identify at this stage, we can use early indicators of likely impacts to understand how the GLE (and associated guidance tools) is understood and accepted in the region and how it is likely to be used in the future. This assessment will explore early indicators of academic impact, conceptual impacts (changes in awareness and understanding), and capacity-building impacts generated by the GLE project. The assessment relies on reports and other outputs produced by the GLE project team, interviews with five members of the science advisory committee, and an interview with one member of the research team.

Academic Impact

Academic impact is most often measured through standard academic metrics such as number of academic publications, the impact factor of the journal(s) where the research is published, and the number of citations garnered by a particular publication. In recent years many questions have been raised about the appropriateness or accuracy of these metrics as indicators of research quality (Hicks et al. 2015; Adler and Harzing 2009). In this case, the metrics are not yet useful because the GLE publication (Briley et al. 2020) is too new to be assessed using these standard metrics. As the project progresses, it will be helpful to track where it is cited (both academic and practitioner-focused products) as well as alternative metrics such as media and social media coverage. For example, even in the short time since the paper has been published, it has been listed on the Skeptical Science blog under "new science" twice and has been posted on Twitter by four organizations (plus by GLISA and the American Meteorological Society, who published the paper). While social media impact is only one aspect of a paper's impact, it's dissemination beyond the journal is an indicator that it may receive more attention from academics and practitioners in the future.

This project has the potential for academic impacts in two distinct, but related areas: innovations in generating robust, credible projections about the GLB and innovations in providing guidance on the evaluation of climate models for use in particular contexts. Briley et al. (2020) has already begun to address this second theme. Future publications may address the first more directly and should be included in future project assessments.

At this stage of project outputs, we can use the perceptions of credibility and salience of those with firsthand knowledge of those close to the project – in this case the scientific advisory committee (SAC) – to understand its early impacts. The SAC members interviewed for this assessment all agreed that the GLE project is important because of the need for accurate climate data about the future of the Great Lakes Basin (GLB). They all noted that the project is necessary because the GLB climate system functions differently than other regions because of the lakes, so relying on climate models that do not capture these dynamics leaves decision makers without important information about regional concerns like future lake levels, surface temperatures, and ice cover.

Michael Notaro, a SAC member who is also an academic researcher, described the GLE effort as "highly valuable to my work" because of the region-specific data it can provide. Drew Gronewold, another academic researcher on the SAC, highlighted a likely future academic impact – by providing this binational dataset, the GLE project will speed the work of future Ph.D. students who will no longer need to spend the first phase of their limited research time preparing datasets. Joe Barsugli echoed the project team's focus on the importance of integrating stakeholder input into the research process to enhance its credibility and usability. He said, the projects "treats evaluation, dialogue, and credibility as joint issues between the stakeholders and the scientists."

Conceptual Impacts

SAC member Glenn Milner noted that not everyone in the region is aware that climate models do not necessarily capture the Great Lakes well, which could have implications for how they interpret and understand publicly available climate data. The GLE project helps to close this gap in knowledge. Another SAC member stressed the strength of the GLE project in the way it combines the science of model evaluation with easy-to-communicate products. She recently used the model evaluation tool to guide model selection for a regional climate change impacts assessment. In an indication of a high level of trust in the evaluation tool she has shared it widely within her professional circles, which include representatives from federal, state, provincial, tribal, and municipal governments; academics; and non-governmental organizations.

The GLE evaluation tool also reached a broad audience through the 2019 State of Climate Modeling in the Great Lakes Basin workshop, where Laura Briley presented the GLE work. The workshop was initiated by Environment and Climate Change Canada and held in Ann Arbor. The GLE project's summary of Great Lakes representation in CMIP5 models was included in the workshop report, which may increase its reach beyond those present at the workshop.

Capacity Building Impacts

The importance of the binational nature of the data was discussed by several SAC members. Glenn Milner explained that Canada does not yet have its own Great Lakes-specific climate data, despite the economic and social importance of the GLB to the country. He also explained that the Province of Ontario lags behind the rest of Canada and the US in producing climate data for the region. GLISA's Great Lakes-specific data boosts the capacity of provincial scientists as well as decision-makers at the provincial and municipal scale to assess climate impacts and make informed adaptation decisions. In the near-term, the Province of Ontario is undertaking a climate change assessment and will need high-quality data about the GLB. He noted, however, that because the influence of the Great Lakes diminishes farther away from the basin, Ontario will need to find data and an approach that is effective for the GLB as well as the far north of the province.

Next Steps

The work of model evaluation is an on-going effort. As new global and regional models are released, GLISA will continue to play a role in assessing their usability in the GLB. As part of the ongoing effort, one SAC member recommended that GLISA publish a reflection or assessment of what the challenges have been with the model evaluation process so that others can learn from their efforts and possibly avoid some of the technical and logistics hurdles the GLE team has faced. Another recommendation from a SAC member is to reach out to other stakeholders who work in the region, such as the Army Corps of Engineers and the hydropower industry, both of which are regularly involved in decisions that will be affected by future Great Lakes conditions. A third suggestion was that the project could provide guidance on how to find and access the models used in the ensemble, for those users who wish to undertake their own analysis.

Based on this preliminary assessment and the early indicators of impact, there are likely to be a range of outputs and impacts generated by the GLE project in Phase 3. To understand the impact of this project, there are several assessment efforts that should occur in Phase 3.

- In order to understand the academic impact of the project, use both standard bibliometrics and Altmetrics to identify citations of the work in the academic and non-academic literature. Based on Gronewold's assertion that the GLE will speed doctoral research in the future, its use in theses and dissertations could be considered as a separate impact category.
- Track the roll-out of the planned products from the GLE project (such as factsheets and maps for decision makers, customized syntheses for specific applications, and raw data) and follow-up with recipients of any products to assess accessibility of the products, perceived usefulness, and examples of use.
- Track the use of GLE products by GLISA researchers and gather feedback on where and in which contexts the products are most useful and usable.
- Although it was not feasible for this report, a Phase 3 assessment should begin with interviews of the stakeholder working group focused on their contributions to the GLE products as well as anticipated and actual uses of the products.

Summary of Cases

These five cases all fit well into what Muhonen et al. (2020) call the collaboration pathway in which a researcher collaborates regularly with stakeholders and/or impact is gained through inter- or transdisciplinary approaches. However, within the broad collaboration pathway, they represent three different sub-pathways. The first pathway involves tailoring and customizing climate analyses to fit within a decision-making or planning processes. The customization necessarily requires engagement between researchers and societal partners to ensure the analysis is usable. Both the *Lac du Flambeau* and *Fort Custer* cases exemplify this approach. In both cases, GLISA researchers were asked to produce climate analyses for a particular purpose and a particular region. The skill of GLISA climatologists – both in climatology and in engagement contributed to their ability to generate fit-for-purpose data.

The second pathway is the production of user-driven or user-informed tools or processes that enhance an organization's ability to undertake adaptation planning. *Future Scenarios for Lake Ontario*, *Stormwater Vulnerability Assessment*, and *Fort Custer* all provide examples of this process. GLISA (or GLISA-affiliated) researchers drew on their knowledge of user needs to develop scenario planning processes (Fort Custer and Lake Ontario) or assessment processes (Stormwater) that allowed their partners to work through complex, uncertain questions about future conditions and their capacity to manage and adapt. The adoption of scenario planning by NYSG and several departments in NYS government because of their experience with scenario planning is a testament to the usefulness of the process.

The *Frost Risk* study – although in early days – represents a pathway built on long-term partnerships between the PI and stakeholders and the subsequent deep context knowledge of the GLISA researcher. Although this project had yet to undertake formal engagement with agricultural producers, the PI's in-depth knowledge of the agriculture industry and strong ties to Extension agents has contributed to the development of an applied economics and climate science project well-grounded in the specific needs of the agricultural community.

Like the *Frost Risk* study, the *Great Lakes Ensemble* project is still in the early stages of actionability. However, there are multiple indicators that point to its likely impact. There is broad agreement among the project's science advisors about its importance both in answering salient questions about the Great Lakes region and in developing methods for evaluating models. The first publication from the project has been circulating in the scientific social media sphere, indicating a recognition of the importance of the topic. The early work of the project is already helping to fill gaps in data availability, particularly in Canada where Great Lakes Basin-specific climate data is not yet widely available.

Because GLISA is a diverse organization, it is likely to continue to rely on multiple pathways to achieve impact – pathways that can be designed and determined based on GLISA staff expertise, available resources, and partner needs and capacity. In the Recommendations section, I discuss ways that GLISA researchers can be more intentional about planning for impact and demonstrating that impact to the research community, funders, and their societal partners in the Great Lakes region and beyond.

Recommendations

Based on my review of past GLISA project and annual reports as well as the compilation of this set of case studies, I offer three recommendations for strengthening GLISA's practices related to planning for, demonstrating, and assessing its impact in the Great Lakes region.

- Use a broad range of impact categories to demonstrate the effectiveness of GLISA's work. Instrumental impacts are the easiest to point to – but they only capture one type of impact and a type of impact that often takes time to emerge. Demonstrating the conceptual, connectivity, and capacity-building impacts that can a) indicate the likelihood of future instrumental and socio-ecological impacts and b) help GLISA researchers and others to understand the diversity of ways that GLISA's research makes a difference in the region. This type of impact reporting also aligns with several prominent international efforts[2], potentially helping GLISA-affiliated researchers more easily connect with international collaborators and compete for international funding.
    - However, GLISA should not become overly reliant on these shorter-term impacts to demonstrate its effectiveness. While these shorter-term impacts are important in-and-of-themselves, they can also be valuable in their role as indicators of the likelihood of future impacts. Organizations like GLISA seek to contribute to long-term, meaningful changes in their region, so it is worth the effort and resources to establish impact assessment practices that allow GLISA to plan for, identify, and demonstrate both short-term and long-term, large-scale impacts.
    - Beginning with a standard set of impact categories, like the ones used in this report, will provide consistency in reporting to start this process. Including an "other" category when asking researchers and societal partners to describe the impacts as they perceive them will ensure that unanticipated (or potentially negative) impacts are not ignored. And in the case of any negative impacts (sometimes called "grimpacts"), acknowledging them provides GLISA with an opportunity to respond and course-correct where necessary.

- Continue to invest in enduring connectivity. Enduring connectivity may be one of the harder impacts to achieve, given the funding model for much of climate science research that provides short-term funding for individual projects (2-3 years, usually). However, connectivity can tell us a fair bit about a project's success – if societal partners want to maintain contact, that tell us they trust the scientists; if participants remain in contact, it may be easier to start-up new projects that build on previous work (and thus accomplish more in a shorter amount of time); and if information sharing is maintained, both parties are continuing to learn from each other, which means that any future work is likely to be better-informed both about the science and the use-context. A program like GLISA that can persist for multiple funding cycles makes it easier to maintain connectivity. But, even within this program, there are examples where circumstances made it difficult to maintain connections between researchers and stakeholder partners. Omar Gates discussed feeling disappointed

[2] See for example the United Kingdom's Research Excellent Framework (https://www.ref.ac.uk/), the Netherlands' Standard Evaluation Protocol (https://www.knaw.nl/nl/actueel/publicaties/standard-evaluation-protocol-2015-2021), and Research Impact Canada (http://researchimpact.ca/).

that his other work commitments meant he could not stay with the *Lac du Flambeau* planning process until the end. In the *Stormwater Vulnerability* project, connectivity was lost when the lead PIs turned over (which is, of course, something we can and do expect to happen on occasion). Finding ways to a) maintain connections with stakeholders, such as through consecutive projects and networks like GLCAN is worth the opportunity costs for GLISA and b) tracing connections and networks can help demonstrate the extent to which GLISA is trusted and relied-upon in the region as well as provide GLISA researchers with easier access to stakeholder input on new projects.

- Using impact pathways plans for GLISA projects may help the program both generate more impacts, because researchers are planning for them, and documenting more impacts, because they will be looking for and retaining evidence of impact. Providing support for and training in impact pathway planning and societal impact evaluation will help to increase GLISA researchers' impact literacy, or understanding of societal impacts, how to produce them through appropriate research and engagement practices, and the support for these practices in the institution (Bayley and Phipps 2019).
    - Below are sample protocols for pre-project impact pathway planning and post-project assessment.

Impact Planning Protocol

Complete at start of project or as part of proposal-writing process

Project Title

Societal or Environmental Issue

What societal or environmental problem do you aim to address in your research? Who is affected by this problem? Who will likely use and/or benefit from your research?

Inputs

What resources are available or necessary to conduct your research?
What skills and expertise does the research team bring to this project? What skills and expertise do societal partners bring to this project? Are you missing any key skills or expertise?

Anticipated Activities

What actions will you take to address the societal issue? This should include a brief summary of research methods as well as engagement and collaboration activities and practices you plan to use throughout the project.

Anticipated Outputs

What do you plan to produce through your research?

- *Research outputs might include, but are not limited to:*
  - *Public Outreach Materials*
  - *Models/Datasets*
  - *Reports for Partners*
  - *Fact Sheets*
  - *Websites*
  - *Peer-reviewed articles*
  - *Curricula*

Anticipated Impacts

What do you expect to change as a result of your activities, your interactions with partners, and your project outputs?

- **Instrumental impacts** – research (evidence and/or process) led to changes to plans, decisions, behaviors, practices, or policies
- **Conceptual impacts** –research contributed to changes in people's knowledge about or awareness of an issue
- **Capacity building impacts** –research contributed to enhancing the skills, expertise, or resources of an organization or group of people

- **Connectivity impacts** – research led to new or strengthened relationships, partnerships, or networks that endure after the project ends
- **Culture/attitude impact** – the research has changed the researcher's attitude toward engagement/collaboration with societal partners and the concept of societal impacts
- **Socio-ecological impact** – research contributes to beneficial social and/or ecological changes after its application to plans, decisions, behaviors, practices, or policies; often a long-term impact.

For whom do you expect things will change?

Evidence of Impact

How will you know that things have changed?

- Describe your plan to collect, document evidence of change. Some examples include:
  - Feedback from your partners
  - Reference to your work in management or policy documents
  - Feedback from the general public
  - Formal evaluation of your work

Impact Assessment Protocol

Complete at the end of a project and update annual post-project to capture new impacts

Project Title

Summary Statement of Impacts

Return to this section after you have completed the rest of the worksheet.

Summary of Societal or Environmental Issue

What societal or environmental problem did you aim to address in your research? Who is affected by this problem? Who did you think was most likely to use and/or benefit from your research?

Project Activities

What actions will you take to address the societal issue? This should include a brief summary of research methods as well as engagement and collaboration activities and practices you used during the project. If activities are different from what you planned, provide a brief explanation of why you needed to make changes.

Research Outputs

What did you produce through your research?

- *BRIEFLY* describe your research findings
- *Tangible research outputs might include:*
  - *Public Outreach Materials*
  - *Models/Datasets*
  - *Reports for Partners*
  - *Fact Sheets*
  - *Websites*
  - *Peer-reviewed articles*

Details of Impacts

What changed as a result of your activities, your interactions with partners, and your outputs?

- **Instrumental impacts** – research (evidence and/or process) led to changes to plans, decisions, behaviors, practices, or policies
- **Conceptual impacts** –research contributed to changes in people's knowledge about or awareness of an issue
- **Capacity building impacts** –research contributed to enhancing the skills, expertise, or resources of an organization or group of people
- **Connectivity impacts** – research led to new or strengthened relationships, partnerships, or networks that endure after the project ends

- **Culture/attitude impact** – the research has changed the researcher's attitude toward engagement/collaboration with societal partners and the concept of societal impacts
- **Socio-ecological impact** – research contributes to beneficial social and/or ecological changes after its application to plans, decisions, behaviors, practices, or policies; often a long-term impact.

For whom did things change?

Evidence of impact

Examples of evidence of change

- *Feedback from your partners*
  - *Formal (letters of recommendation or partnership)*
  - *Informal (email or phone calls)*
- *Reference to your work in a management/policy document*
  - *Citation to support statements*
  - *Research findings forming the basis of policy document*
  - *Citation in management reports or publications*
- *Feedback from the general public*
  - *Audience surveys*
  - *Emails or other engagement from public*
  - *Media interviews/reference to your work*
- *Formal evaluation of your work*
  - *Randomized control trials*
  - *Pre-post tests*
  - *Surveys/interviews of partners*

II. The Role of GLISA Graduate and Undergraduate Research Assistantships in Supporting Student Career Development and Societal Impacts

Introduction: GLISA's role in Reform of Graduate Education

Graduate and undergraduate research assistantships make up a significant portion of GLISA's activities. GLISA has funded 31 different students during Phase 2 (2015 – 2020), with many of them completing multiple assistantships. Given the scope of this investment, it is important for GLISA to understand the impact the program is having on the long-term academic and career trajectories of students who participate in research assistantships. The following rapid assessment seeks to identify common themes within students' experiences of GLISA in order to shed light on its current impact and make recommendations for monitoring and assessment of student impacts in Phase 3 of the program. While GLISA does fund several undergraduate assistantships (5 of 31 students), the vast majority are graduate assistantships. This report will focus on issues related to graduate student education. However, the assessment included one undergraduate student to ensure that the full range of students was considered.

A recent report by the National Academies of Science, Engineering, and Medicine (NASEM) on graduate science, technology, engineering and math (STEM) education noted several gaps in traditional graduate education that will leave students unprepared for 21st century challenges. Of particular note was the finding that "many graduate programs do not adequately prepare students to translate their knowledge into impact in multiple careers" (National Academies of Sciences 2018, 1). A related finding by Okahama and Kinoshita (2018) is that former STEM graduate students who work outside of academia reported feeling less prepared for their careers than those who stayed in academia. This is an educational gap that GLISA is in an excellent position to fill.

NASEM's report proposes a number of reforms to graduate education that will help to address these gaps. Below, the 11 key reforms are briefly summarized. Many of the reforms pertain to classroom- and academic department-based changes outside the scope of GLISA's work with students. However, a number of the proposed reforms are directly relevant to the types of hands-on experiences GLISA strives to provide for students. Those proposed reforms particularly relevant to GLISA's role in providing graduate research experience are noted in italics.

- Prospective graduate students would be able to select their graduate program aided by fully transparent, easily accessible data [about the program].
- Students would acquire broad technical literacy coupled with deep specialization in an area of interest.
- Students from all backgrounds would fully participate and achieve their greatest potential during their education experience . . .
- *Students would encounter a variety of points of view about the nature, scope, and substance of the scientific enterprise and about the relationships between science, engineering, and society, and they would be encouraged to understand and grapple with differences of opinion, experiences, and ideas as part of their graduate education and training.*

- *Students would have opportunities to communicate the results of their work and to understand the broader impacts of their research.*
- Students would be encouraged to create their own project-based learning opportunities.
- *Students would be encouraged and given time, resources, and space to explore diverse career options, perhaps through courses, seminars, internships, and other kinds of real-life experiences.*
- Graduate programs and departments would develop more efficient channels for students to communicate with the administration and faculty regarding processes and decisions within the department and the graduate school that affect graduate student education.
- Graduate programs would develop course offerings and *other tools to enable student career exploration and to expose students to career options*.
- *Institutions would help students identify advisors and mentors who can best support their academic and career development.*
- Institutions would provide faculty with training, resources, and time both to improve their own skills as mentors and to provide for quality mentoring and advising to [students].

This assessment of GLISA's impact on student academic and career trajectories focuses primarily on its role in helping to prepare students to work in careers related to applied/engaged climate science or other career paths of their choosing.

Methods

This rapid assessment is intended to identify common themes emerging from the experiences of GLISA research assistants related to career trajectories and career impacts as well as to inform a monitoring and assessment plan for GLISA's Phase 3. This assessment is based on the experiences and opinions of a sample of GLISA's 31 Phase 2 graduate students (6 of 31 total students; approximately 20%). I endeavored to stratify the sample so as to reach as many different categories of students as possible: PhD, MS, and BS as well as students from the three institutions represented (UM, MSU, and Brown). The majority of students were from UM (24/31) with 4/31 coming from MSU, and 2 undergraduate students from Brown. Interviewees were selected randomly from each of the categories. I was not able to contact the Brown students. I interviewed one BSE student from UM, two MEng students and one MS/MBA student from UM, one PhD student from UM, and one PhD student from MSU.

All interviews were conducted by videoconference or phone. Each interview lasted approximately 30 minutes and focused on participants' experiences with GLISA including the projects they worked on, skills built through their GLISA assistantship, career trajectory since their work with GLISA, and recommendations for future cohorts of GLISA research assistants.

Findings

Skills

The most common skill developed through a GLISA assistantship, mentioned specifically by 5 of the 6 interviewees was "communicating science" in ways that make science useful to stakeholders. The only person who did not name communication as a key skill developed through GLISA work may have already had this skill due to previous work and academic

experiences. A common theme was that the interviewees had developed an ability to reflect upon how to make science useful and communicate about the science in a way that was relevant to the societal partners with whom they worked. The interviewees noted that this skill was developed "by doing" because they had the opportunity to work directly with GLISA's community and agency partners during their assistantships. Hands-on experience with societal partners was described by three interviewees as key to developing skills related to stakeholder engagement. Two interviewees also described the importance of developing skills related to data analysis aimed at societal impact – for example, learning to analyze data at a regional scale because that is important to stakeholders and evaluating climate model uncertainty with an understanding of the role of uncertainty in stakeholder decision making.

Several participants also noted that it was throughout GLISA that they had their first opportunities to present research in public and/or at academic conferences. They considered this a highly beneficial experience.

Careers/Career Goals

Four of the interviewees have already completed their education and moved into professional roles. Two (both PhD candidates) expect to do so within the next year. Overall, all six interviewees expressed an interest in applied climate work. Two currently work for government agencies in fields related to climate change, but not directly involved in climate change science. Both have firm plans to move into more climate focused work as soon as it is professionally possible. One interviewee works in the utility industry and is focused on renewable energy issues. One interviewee works with a start-up firm focused on providing technical analyses for community resiliency and health issues. The two PhD students both expressed a strong desire to continue applied, societally relevant climate research in their future careers.

All of the interviewees were able to provide specific examples of how their work with GLISA has helped steer their career trajectories toward their desired work and jobs. An important reflection was that the hands-on experience a GLISA assistantship provided working with communities and other stakeholders helped the interviewees land their current jobs. One reflected that in a competitive job market, where even entry-level positions seem to expect several years of experience, her GLISA experience filled that role. Another pointed to her specific experience with the theory and practice of co-production of knowledge as key to being offered a prestigious position in her desired field.

Two interviewees each remarked that they felt they started their work with GLISA seeing it as "just a job" to cover tuition, but ended up finding the experience fundamental to their career development. One participant summarized her thoughts on how GLISA prepared her for her career this way: "Every time I apply for a new job, I get a new appreciation for what I learned with GLISA."

Challenges and Recommendations

The overall response from interviewees was that their experience with GLISA had been very positive and was directly contributing to their successful career paths. They also reflected on some challenges of their GLISA experience and suggested how the assistantships might be strengthened in Phase 3.

A challenge described by several interviewees was that they felt work within GLISA was somewhat siloed – the climate and social scientists did not work as closely as interviewees would have liked, which reduced opportunities to learn about each other's disciplinary expertise. Another participant perceived some disconnect between the core office at UM and the team members at MSU that reduced opportunities for collaboration.

Most of the interviewees reported that they did not have one consistent supervisor for their GLISA work – but had worked on several different projects. While the experience of working on multiple projects was considered a positive by all interviewees, the lack of consistent oversight created some challenges in terms of clarity of expectations. For example, one student noted that she felt she had to struggle on her own to complete analysis for a project, while another felt she could have taken on more responsibility but it wasn't offered. The lack of consistency was also raised by several people in the context of not seeing the final product of projects they contributed to because they had moved to new projects once their tasks were completed on older projects.

Echoing the NASEM recommendations, several interviewees recommended that GLISA integrate more direct career advice and mentoring into the program. They noted that many of the GLISA researchers are doing the kind of applied climate research the participants want to pursue – and they would have liked more opportunities for career mentoring.

Summary

Participants in GLISA's research assistantships interviewed for this assessment found their experiences with GLISA to be positive and beneficial to their career trajectories. In particular, the hands-on experiences of working with stakeholder communities and agencies provided experiences they could not get through coursework, or in many other traditional research assistantships. Each one of the interviewees could point to specific skills, knowledge, or experience gained through their time with GLISA that directly and positively impacted on their careers. GLISA appears to play an important role in filling some of the gaps in traditional graduate education identified by NASEM such as:

- Engagement with societal partners provides opportunities for students to encounter a variety of points of view about the nature, scope, and substance of the scientific enterprise and about the relationships between science and society.
- Working on "real world" projected provides opportunities for students to communicate the results of their work and to understand the broader impacts of their research
- Participation in the process of moving science into action as well as working closely with applied/engaged climate scientists provided opportunities for students to explore diverse career options [through] real-life experiences.

Recommendations for Research Assistantship Monitoring and Assessment in Phase 3

GLISA's goal is to support the training of students in such a way as to maximize their future beneficial societal impacts. In order to ensure that the positive results summarized in this assessment continue into the next phase, GLISA can put in place more regular monitoring and assessment of student learning outcomes and career trajectories. A short survey delivered to past GLISA research assistants on a regular basis, approximately every 2-3 years could help GLISA both understand its current impact and ensure that its research assistant opportunities keep pace with the changing needs of academic and non-academic employers. The Student Lifecycle Project at Wayne State University (Feig et al. 2016) found that students should be tracked for 15 years post-graduation to adequately capture their career development because we should expect students to change jobs several times, particularly within the first 3-5 years after graduation.

Suggested survey topics are summarized below.

Question	**Purpose**
Name, degree, years with GLISA	Tracking participants. Data can be collected when student first starts with GLISA.
GLISA projects worked on	Potential to assess benefits of particular project(s) and/or benefits of multiple vs. single project experience.
GLISA assistantship supervisor(s)	Potential to assess the role of mentorship/advising in career decisions.
Demographics (gender, racial/ethnic identity, degree sought, institutional affiliation)	Helps to determine the extent to which GLISA is contributing to broadening participation in science through access to its research assistantships. Data can be collected when student first starts with GLISA.
Current job title and brief description	Track job changes and career progression.
Industry • Government • private industry • Non-profit • Higher-ed – PhD granting institution/non-PhD granting • Other (open-ended so respondents can describe)	Determine which careers/industries GLISA experience most supports.
Location	Assess whether GLISA students stay primarily in the Great Lakes region or whether their skills and experience are broadly transferrable.
How/whether GLISA experience is contributing to their current job and/or career trajectory.	Open-ended question to assess alignment between GLISA experience and career preparedness.
What skills/experiences they recommend GLISA assistants gain to make them competitive and successful in their industry.	Open ended question to help GLISA respond to workforce changes.

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