A REVIEW OF GREAT LAKES WEB-BASED GEOSPATIAL INFORMATION TOOLS

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A Review of Great Lakes Web-Based Geospatial Information Tools

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Executive Summary

This report contains the results of a review of web-based geospatial information tools for the Great Lakes region. It was conducted to inform the development of a new decision support system (DSS) related to a project to develop a geospatial database and classification framework for Great Lakes aquatic habitats, the Great Lakes Aquatic Habitat Framework (GLAHF). The report contains a discussion of key informant interviews, a systematic review of tools which met our criteria, and a discussion of several comparison tools. We identified 37 web-based Great Lakes information tools which provide spatial information, cover at least an entire Great Lake, U.S. state or larger extent, is relevant to researchers and/or resource managers, and can be accessed via the web without payment or permission. We completed a quantitative inventory and qualitative assessment of the tools' data availability, functionality, and other details. We also identified 16 comparison tools to inform tool development in the Great Lakes. A complete listing of these tools are included as Appendices to this report.

Although a substantial amount of data are available through these tools, we found they had uneven spatial and topical coverage. The most common types of data included were physical or chemical information such as air and water temperatures, nutrient concentrations, and water levels. A majority (59%) also contained some type of biological data, such as the prevalence and location of various plant and animal species. Collectively we identified several gaps which GLAHF-DSS could help fill. Less than half of the tools provided binational coverage (38%) or fine-scale data (46%), which we defined as data at a resolution of approximately 30 meters or less. In addition, only 16% provided data focused on the ecologically important coastal margin, which we define as extending from the ordinary high water mark to three meters depth. There was also a lack of human activity and policy data.

In addition to the data gaps, we observed that many of the existing tools focused on specific topic areas, did not emphasize the interconnected nature of ecosystems, and provided users only a limited ability to provide customized analysis. In order to explore these issues, the report identifies comparison tools which demonstrate functionality that could be replicated in the Great Lakes. In light of these findings and the goals of the GLAHF-DSS project, we arrived at six main observations about the existing Great Lakes geospatial information tools:

1. Most tools lack a holistic habitat perspective;
2. Few tools contain integrated data between aquatic and terrestrial ecosystems, and data about the coastal margin;
3. Most tools have a relative lack of human activity and policy data;
4. Many tools lack fine-scale data, especially across national boundaries;
5. Many tools lack downloadable data;
6. Few tools offer analysis and prediction functionality.

We conclude Great Lakes geospatial information tool developers could focus on these areas to build on the already rich set of tools available to Great Lakes environmental researchers, managers, planners, and policymakers.

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1. Introduction

In recent years, use of the web to share geospatial information has expanded rapidly. Spatial information is increasingly available for download from public websites, and developments in web mapping technology have resulted in many interactive maps that allow users to view, query, and analyze information without relying on desktop geographic information systems (GIS) software. These developments are potentially useful for environmental management and policymaking, as they can place detailed information at the fingertips of diverse stakeholders. For example, a recent survey of Fisheries Management Agencies found strong interest in GIS, but also that limited access to GIS software and sufficient training served as a barrier to broader use by these agencies (Eder and Neely 2010).

Researchers, governments, and other stakeholders have taken advantage of these developments to create a wide range of web-based mapping tools for the Great Lakes. This document reports the results of an analysis of these tools conducted in order to inform the creation of a new decision support system (DSS) related to a novel project to categorize and map Great Lakes aquatic habitats, the **Great Lakes Aquatic Habitat Framework** (GLAHF).

This report describes the results of two related investigations:

(a) **Key informant interviews** among individuals selected to maximize diversity in three dimensions: jurisdictions (within and between the U.S. and Canada), spatial scale of analysis, and regulatory domains (e.g., fisheries, coastal zone management, water quality, etc.). Each interview described the needs that current tools fill and the context of their use. Collectively, they provided a check on the completeness of the tool review, as well as a richer interpretation of the gaps and needs than the primarily quantitative review provided.

(b) A **systematic review** of **37** web-based Great Lakes geospatial information tools, complemented with observations from 16 additional tools not focused on the Great Lakes. This review assessed these tools' spatial coverage, data availability, technical functionality, usability, maintenance, and provides an overall evaluation. This review sought to identify gaps that GLAHF-DSS might fill, as well as identify best practices for tool development. Each tool has been assigned a unique identifier, and a complete list is provided in the appendix.

Project Background

This review was implemented as an outreach and implementation aspect of the GLAHF project, an aquatic habitat database and classification framework integrating key habitat

components—for background see (Riseng et al. 2008; Riseng et al., forthcoming). The project has three primary products: (1) a novel spatial framework, (2) a database of spatial data, and (3) an aquatic habitat classification framework. The spatial framework consists of geo-referenced grid cells that cover the entire Great Lakes basin with a focus on coastal and nearshore systems (Figure 1). These grid cells can be aggregated into larger functional units. This hierarchical structure provides the framework for developing a Great Lakes habitat classification system that can be used at the spatial scale appropriate for the development of regulatory policies, prioritizing management activities, and identifying jurisdictional responsibilities. A suite of data that describes physical and chemical, biological, human activity, and policy aspects of the Great Lakes ecosystem has been referenced to the grid cells in the spatial framework. Building on the framework and database, GLAHF is developing a habitat classification tailored to the Great Lakes. Habitat classes are ecological unit types that are nested in the five ecological zones of the classification framework: watershed, coastal terrestrial, coastal margin, coastal nearshore, and offshore.

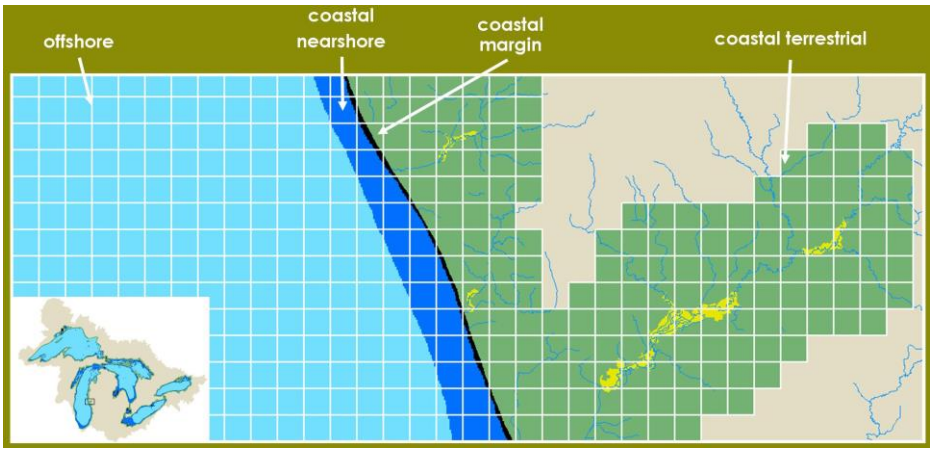

Figure 1. GLAHF Framework

Definitions

This section provides an overview of some of the terms used in this report.

The term **Decision Support System** (DSS) and the related concept of a spatial DSS (SDSS) has been used to refer to a variety of types of tools, ranging from those which simply make information available, to those which implement forms of analytical modeling or analysis. This project adopts a broad perspective, following the definition offered by Janssen (1992) that a DSS is a tool which (1) assists individuals or groups in their decision process, (2) *supports* rather than *replaces* judgments of individuals, and (3) improves the effectiveness rather than the efficiency of the decision process. This definition provides more specific details than Densham (1991) who defined a SDSS as allowing for “the analysis of geographical information to be carried out in a flexible manner.”

This project uses the term **aquatic ecosystems** to refer to regions of the Great Lakes greater than three meters depth, thus covering GLAHF's nearshore and offshore zones exactly. For purposes of analysis, **terrestrial ecosystems** are areas located above the ordinary high water mark, including not only land but also rivers and inland lakes. This definition covers GLAHF's coastal terrestrial and watershed zones. Finally, the **coastal margin** extends from ordinary high water to three meters depth.

Resolution refers to the level of spatial acuity, or detail, represented within data. This tool survey categorizes the data made available by each tool based on the type of analysis they make possible. **Fine-scale data,** at a resolution of approximately 30 meters or less, are appropriate for making decisions about localized phenomena, such as shoreline construction or lakebed disturbances. **Intermediate-scale data,** at a resolution of less than one kilometer, can be used to make policy decisions affecting an entire municipality or section of shoreline. **Broad-scale data,** with resolutions measured in the kilometers, are best for making recommendations affecting a Great Lake or the entire basin.

In categorizing **types of data,** the tool survey used a set of categories condensed from GLAHF data. Thus, **physical/chemical data** includes topobathymetry/slope, geomorphology, mechanical energy/hydraulics, temperature energy, and water chemistry, rivers/hydrology as well as unprocessed imagery. **Biological data** covers aquatic biota data as well as wetlands/aquatic vegetation. Meanwhile, **human activity data** includes land use data, shoreline modifications, economic output, and shipping, and **policy data** includes designations of conservation priority, protection, or similar status, such as EPA Areas of Concern.

Previous Research on Tools for Marine Policy and Planning

Since web-based geospatial information tools are a relatively recent development in the Great Lakes, no previous review of these tools was found in the scholarly literature. This section describes previous research in several related areas: the use of habitat information in the policy process, adoption of DSS by policy makers, and tool development in the field of marine spatial planning.

Although research has found information must make it to the hands of decision makers to be used in management and policy, research on DSS has found several challenges face efforts to design tools to meet this goal. Research focusing on the adoption and use of information and technical tools by policymakers has found information is best disseminated directly to stakeholders making decisions, and this group should also be involved in the

development of any DSS. A study of a project in Maine which disseminated simplified information about the location of priority terrestrial habitats found DSS was used for policymaking more often when the project was not led by municipal planners (Kartez and Casto, 2008). The study emphases the importance of providing scientific information directly to policymakers, as well as ensuring tools and information are available and useful to a broad variety of stakeholders. A study of spatial decision support systems in the Netherlands found that many were not used by practitioners. The study authors argue this could be avoided by creating a closer link between tool developers and users (Uran and Janssen, 2003). This finding echoes other research that emphasizes the importance of engaging multiple stakeholders during the problem specification and model building stages of constructing a DSS (Shim et al. 2002). As a consequence of this and the related literature on the lack of adoption of planning support systems, this project anticipates a participatory development approach which will involve workshops and user testing by the anticipated users.

Although there is limited research on Great Lakes Tools, this report draws on innovations from the developing area of marine spatial planning, an area of active tool research and development. Although physically and biologically distinct from the world's ocean, the Great Lakes share some similarities with ocean policy making because of their large size, multiple conflicting uses, complex regulatory environment, and need to involve multiple stakeholders. Marine spatial planning (MSP) projects have been conducted in many parts of the world's oceans, and MSP is defined as "is a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process" (Ehler and Douvere 2009, on the history of MSP see Douvere 2008, Collie et al. 2013). Given the spatial focus of MSP, maps and spatial data have become the "backbone" of decision-making process (for a discussion of the limitations of maps for MSP, see Smith and Brennan 2010). In addition, U.S. Federal agencies have begun conversations about conducting marine spatial planning for the Great Lakes under the National Ocean Policy, following up on successful planning projects in the Atlantic and Pacific (National Ocean Council 2013). Therefore this section briefly describes the evolving field of tools for MSP.

MSP tools focus on two areas, which influence their applicability to this project. First, much of marine spatial planning has focused on drawing and evaluating marine protected areas (MPA) where various activities (such as fishing or wind turbine installation) are permitted or restricted (e.g., on GIS tools for MPA evaluation see Pattison, dosReis, and Smillie (2004)). Although there is some precedent for this type of management in the Great Lakes, it is not the

only form of management activity GLAHF-DSS hopes to support. However, their emphasis on taking a holistic perspective, such as integrating human uses and biological data, is useful. Many MSP tools focus on analyzing conflict between multiple objectives, such as protecting habitats while also accommodating human activities.

One recent review of tools for marine spatial planning described three prototypes informed by this focus on interactions: an activity count tool, create pressure layer tool, and weighted overlay tool (Stelzenmuller et al. 2013). Two features of this paper suggest a need for the type of tool anticipated by GLAHF. First, the majority of the MSP tools reviewed are targeted for use by scientists, programmers, and other technical users, not case managers or other managers in nontechnical roles. Second, although the paper identifies species conservation and habitat requirements as an important marine spatial planning objective, the prototypes and tools reviewed do not describe tools designed to explicitly represent and analyze habitat information. A broader European research project Measuring and Evaluating Spatially Managed Areas has compiled a large collection of materials which were reviewed for this project (MESMA 2013; on project see Vassilopoulou et al. 2013).

Report Structure and Conclusions

The report structure is as follows. Section 2 describes the methodology of the key informant interviews and the tool review. Section 3 describes the results from the key informant interviews. Section 4 describes the results from the tool review. Section 5 discusses conclusions drawn from these results, and Section 6 concludes.

Drawing on the interviews and systematic review, we identify six weaknesses of the existing tools which can guide the GLAHF-DSS project:

1. Lack of tools with a holistic habitat perspective;
2. Lack of integrated data between aquatic, coastal, and terrestrial ecosystems;
3. Relative lack of human activity and policy data;
4. Lack of fine-scale data, especially across national boundaries;
5. Relative lack of downloadable data;
6. Lack of tools providing for customized analysis.

These gaps are discussed in more detail in section 5.

2. Methodology

This section briefly describes the methodology used for the key informant interviews and the tool review.

Key Informant Interviews

As a preliminary study to inform the tool review, semi-structured telephone interviews were conducted with five knowledgeable professionals working for government agencies across the Great Lakes.

An initial list of potential interview subjects was generated based on their breadth of experience working in Great Lakes resource management and related efforts, and prior contact with a member of the team or with an intermediary who would provide an introduction. The list was augmented through snowball sampling. From the overall list, interviewees were chosen to maximize coverage across three dimensions: jurisdiction, management category, and scale of analysis of professional activities. Because they were chosen for breadth of experience, the primary job responsibilities for most interviewees were managerial, and therefore are likely less involved in mapping and data management activities than potential tool users. The semi-structured interviews were divided into three sections: first, understanding the context of current work activities, including the types of information used in decision-making; second, listing the resources currently used in those activities, such as internal GIS systems or web-based tools; and third, probing unmet needs for information and analysis.

Tool Review

This review included tools meeting the following criteria: tools that (1) provide spatial information which (2) covers an entire Great Lake, entire U.S. State, or larger extent, (3) is relevant to researchers and/or resource managers, and (4) can be used via the web without payment or permission. Many, but not all, are map-based, in that the primary navigation and display of information is accomplished via a map-centered interface. The list was generated through brainstorming by the project team, selected web searches, and through the key informant interviews. Some tool websites included references to related tools, which were also considered for inclusion.

The review of each tool consisted of data collection organized into two broad areas: **quantitative inventory** of data availability and **qualitative assessment** of tool functionality. Quantitative inventory variables included spatial coverage, ecosystem focus, and data output formats, while qualitative assessment variables included technical functionality, usability,

maintenance, and an overall evaluation. (See Definitions for some of the quantitative categories used, and see Appendix for a full list of variables.) Where possible these variables were designed to follow categories relevant to the GLAHF project.

3. Key Informant Interview Results

Interviews confirmed a need for targeted analytical tools that would integrate data and future scenarios in service to Great Lakes resource management. To start with, biological and physical data are indeed essential for the work of managers across the basin. Interviewees did not name many specific web-based tools that they used, instead describing internal data sources and a general approach of following word-of-mouth or topic-based web searches to find data. Two barriers to effective analysis emerged: limited availability of relevant, localized data, and difficulty of linking data across times and types of data. They described sharing data and results currently, and a desire to share data more widely. Finally, a clear need was expressed for projections about ecosystem function in response to changing inputs. Below, we describe each of these findings in turn.

Interviewees

Five managers were interviewed, balanced across jurisdiction (U.S. vs. Canada as well as federal vs. state/provincial), management category, and scale of analysis (see Table 1). No managers dedicated to water quality or beaches were interviewed, but three managers reported responsibilities across multiple categories. All described their work as affecting terrestrial and coastal margin ecosystems, and all but one also dealt with aquatic ecosystems. Three of the five described themselves as users of desktop GIS software; all described in-house GIS expertise within their organizations.

		Scale		
		Great Lake	**Municipality**	**Parcel**
Jurisdiction	**Canadian - Federal**	Environment Canada (multiple categories)		
	Canadian - Ontario		Conservation Authority (multiple categories)	
	U.S. - Federal	USEPA (multiple categories)		
	U.S. - State	DNR (fisheries)		DNR (CZM)

Table 1. Dimensions used for interviewee selection.

Types of Information Used

As expected, all interviewees described using biological and physical/chemical data as part of their work activities. Most also mentioned using data on human activity and policy information. Every manager described using their own agency's data, which their agency had either collected directly or had contracted out for collection, in addition to data from outside sources. Each interviewee played multiple roles in regards to Great Lakes management, including wetlands evaluation, hydroacoustic surveys, interpreting projected impacts of climate change, tribal negotiations, policy review, implementation of the 2012 Great Lakes Water Quality Agreement, and permitting.

Sources of Information

When interviewees were asked what "external websites or other tools" they used to obtain information, they mentioned data-centric websites only three times: two managers mentioned NOAA CoastWatch (reviewed as T22) and one mentioned Tree of Life (a taxonomic website, not included in our review). Other specific websites included the EPA Great Lakes information page and the website of the Great Lakes Fisheries Commission, both of which primarily provide reports, policies, and links rather than spatial data or maps. Almost all interviewees mentioned other people as a source: either researchers who would respond to requests for data, or colleagues who would recommend a website or other resource. At the extreme, one manager found other methods of data discovery ineffective enough that "who you know is where you go"—that personal connections determine the data you can find. Meanwhile, most interviewees mentioned that they perform topic-based web searches to find data, and two mentioned Great Lakes-focused journals.

Data Sharing

In addition to sharing the results of their analyses with supervisors, regulators, and developers, interviewees reported a desire to share data that their organization collected more broadly via the Web. Some resource constraints make this difficult, including the technology, time and expertise to process and synthesize data and to prepare metadata. In addition, institutional procedures often erect barriers to making data public. At a broader scale, one manager expressed concern that of the many efforts to manage and share Great Lakes data, not all will be "sustainable" due to competition and reliance on short-term funding. Thus, this interviewee would want to know which ones will "have staying power" before partnering with any to publish agency data.

Needs and Barriers

A recurring theme that emerged from interviews was a need for the ability to project of how ecosystems would change in response to human and/or climate disturbances. The functionality interviewers described for this included identifying “tipping points” and the ability to observe the effects of differing mitigation measures, shoreline development, and lake level scenarios. The resulting projections are needed in order to inform stakeholders about importance of ecosystem restoration and preservation, to inform conversations about coastal resilience to climate change, and to provide evidence in support of regulatory and permitting activities.

Managers at all scales of analysis—from lake-wide to parcel-level decisions—described a lack of fine-scale nearshore bathymetry data as a barrier to conservation and management activities. Three interviewees mentioned a need for this data which does not consistently exist across the basin today. A fisheries manager described difficulties reducing side-scan sonar data of limited areas into a usable form, while a Coastal Zone manager described wanting fine-scale substrate maps of nearshore areas, “like everyone else [in the field].” Another commonly described need was tools to assist in linking data. Some managers described challenges connecting different types of data, for example to analyze benthic data, water temperatures, and fisheries data together, while others focused on the ability to follow links from visualizations and reports to the source data.

In sum, the interviews highlighted a demand for certain types of information and analysis tools in the Great Lakes, but also illustrated the formidable barriers these tools face. On the one hand, it seems that new tools can complement existing GIS capacity by providing download access to data and providing the ability to link diverse types of data not easily completed by desktop GIS users. On the other hand, many barriers were evident. The interviewees were not familiar with the tools which already exist, suggesting a need for tool creators to more closely collaborate with intended users. In addition, their desire for tools that provide the ability to predict the impact of certain actions may be challenging even for large teams of analysts, and require highly context-specific data.

Surprises

Resource managers interviewed mentioned using very few web-based tools by name, suggesting low levels of tool use or other obstacles. Web-based tools may not be used very frequently by full-time resource managers for a variety of reasons, such as a lack of awareness or a poor match between user needs. Alternatively, interviewees in supervisory roles may deal

less with particular tools than staff assigned more specific tasks. If this is the case, input from junior staff would be essential to the detailed understanding of tool use. It is also possible that less formal methods of tool discovery, such as word of mouth and web searches, are simply more effective than finding tools through web searching or memorizing particular tool names. The last explanation suggests that current tools are not essential parts of managers' workflow, or perhaps that there is enough duplication between tools that the particular choice of tool does not matter. A tool that is closely tailored to the needs and workflow of a specific target audience will be more likely to be used frequently enough to be identified by name. Regardless, the prevalence of web searches and word of mouth suggests that branding, marketing, and search engine optimization will be important to the success of a new tool.

4. Tool Review Results

This section reports the results of the systematic review of 37 Great Lakes tools and selected observations from 16 additional comparison tools. The results will be reported in four sections: overall descriptive statistics of data availability, a detailed analysis of data availability within the Great Lakes basin, a discussion of tool functionality, and observations from the 16 additional tools.

Data Availability Overview

The review revealed a complex landscape of online SDSS tools for Great Lakes ecosystem management, although one with uneven spatial and topical coverage. Out of the 14 tools (38%) with binational coverage, 12 tools provide coverage of the entire basin, while one each covers a single Lake or the entire continent. Both Canadian tools reviewed (5% of total) cover Ontario, the entire sub-national Canadian jurisdiction of the Great Lakes basin. Of the 21 tools (57%) focused within the United States, eight each focus on the full U.S. side of the basin and the entire country (22% of total), while five (14%) are limited to a single State. Several tools available within Canadian government were not included because they did not meet the criteria that tools be publicly accessible and span lake-wide or equivalent extents.

Less than half the tools provided fine-scale data (46%), while most provided intermediate-scale data (78%) and broad-scale data (84%). The tools also differed on their spatial focus, 60% providing terrestrial data, 62% providing aquatic data, and only six tools (16%) providing data focused on the coastal margin. These tools were: Wisconsin Coastal Atlas (T9), Ohio Coastal Atlas (T10), USACE Oblique Image Viewer (T11), GLRI Phragmites DST Mapper (T13), GEO Great Lakes Metadata Catalog (T53), Great Lakes Information Management & Delivery System (T1).

The most common form of information available in the tools was physical or chemical (87%), such as water or air temperatures, nutrient prevalence, or water levels. A majority, 59%, contained biological data, such as the prevalence and location of various plant and animal species. Somewhat less common were data about human activities (54%) and policy information (57%), which included designations of priority, protection, or similar status, such as EPA Areas of Concern.

Although sharing a common focus on spatial information, the means for accessing this information varied. Most tools provided maps or access to download the data in formats that can

be manipulated in GIS software (62% for both). Smaller proportions of tools provided graphs (35%), tabular data (30%), or links to data elsewhere (35%).

Data Availability in Detail

Consistency of Data Availability

The proportion of tools providing fine-scale data and providing data for download was nearly constant across extents, national focus, and ecosystem focus. Fine-scale data was available for 40%-47%, 41-43%, and 41%-52% of tools when separated by state-wide vs. larger coverage, Canadian vs. U.S. coverage, and Terrestrial vs. Aquatic coverage, respectively. Within the same categories, data was available for download within 60%-63%, 59%-63%, and 64%-57% of tools. These averages are nearly indistinguishable from overall averages of 46% availability of fine-scale data and 62% availability of downloads. Tools focused on the coastal margin were the exception on both fronts: 83% provided data or images suitable for fine-scale analysis, but only 33% (two of six) provided data for download.

Jurisdictions

As described in the Methods section, only two publicly available Canadian tools were found that met the study criteria. Because of the paucity of data, it was not possible to make meaningful comparisons between the characteristics of the web-based tools available to resource managers in Canada versus the U.S.

Comparisons between sites with binational extent and those with national or smaller extent showed differences in availability of fine-scale data, types of data, and research focus. Most (52%) of single-country websites include fine-scale data, while only 36% of binational websites do. However, binational tools are much more likely to include aquatic data, which 93% of them do, compared to U.S-only or Canadian-only tools, at 43%. All binational tools contain physical data, compared to 78% of single-country tools. Finally, out of the 22 tools focused on either the U.S. or Canada alone, only one (5%) is research-focused, while 6 of the 14 binational websites (43%) are research-focused.

The five tools reviewed with a state-wide extent were the Pileus Project, Water Withdrawal Assessment Tool, GeoWebFace, Wisconsin Coastal Atlas, and the Ohio Coastal Atlas. Of these, none cover aquatic regions, and only one -- the Water Withdrawal Assessment Tool -- deals with biological data explicitly. The availability of other data and features was similar between sites having state-wide and larger extents, with the unsurprising exception that fewer

state-focused sites contain broad-scale data.

Types of Data Available

Only 12 tools (32%) combine data about terrestrial and aquatic ecosystems, while only two (5% of total) include coastal margin data as well as terrestrial and/or aquatic data. Both of these tools—GEO Great Lakes Metadata Catalog (T53) and Great Lakes Information Management & Delivery System (T1)—are catalogs of external data that meet all three ecosystem criteria, but do not themselves integrate the three ecosystems within a single map viewer or analysis engine.

Tools overwhelmingly either display policy information and human activities, or neither. Both human activity and policy information was included by 49% of tools while 38% included neither, leaving just 14% (5 tools) which containing just one of the two types of data.

The resolution of data provided by a tool did not appear to have an effect on its availability of data by type. That is a visitor is equivalently likely to find biological data at a tool regardless of whether it served fine-scale, intermediate-scale, or broad-scale data. Figure 1 below, shows how likely each type of data (physical/chemical, biological, policy, and human activity) is to be found given a particular resolution.

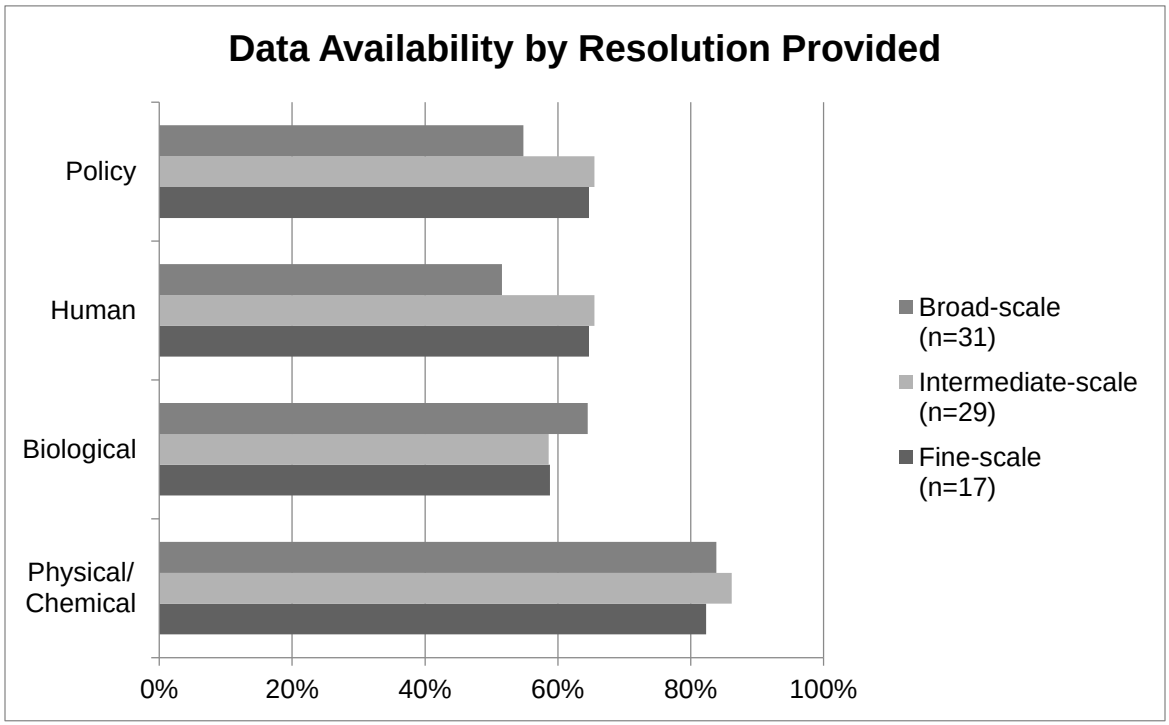

Figure 2. Data availability by resolution and type.

Evaluating tools based on their ecosystem focus, tools covering terrestrial ecosystems tended to integrate *more* types of data into each tool. That is, a tool providing terrestrial coverage is more likely to include physical/chemical, biological, human activity, *and* policy data than one covering aquatic ecosystems. Figure 3, data availability by ecosystem served, shows increased terrestrial availability of each type of data. In all, the 22 tools covering terrestrial ecosystems provided an average of exactly 3 types of data, while the 23 tools covering aquatic ecosystems included an average of only 2.57 types of data.

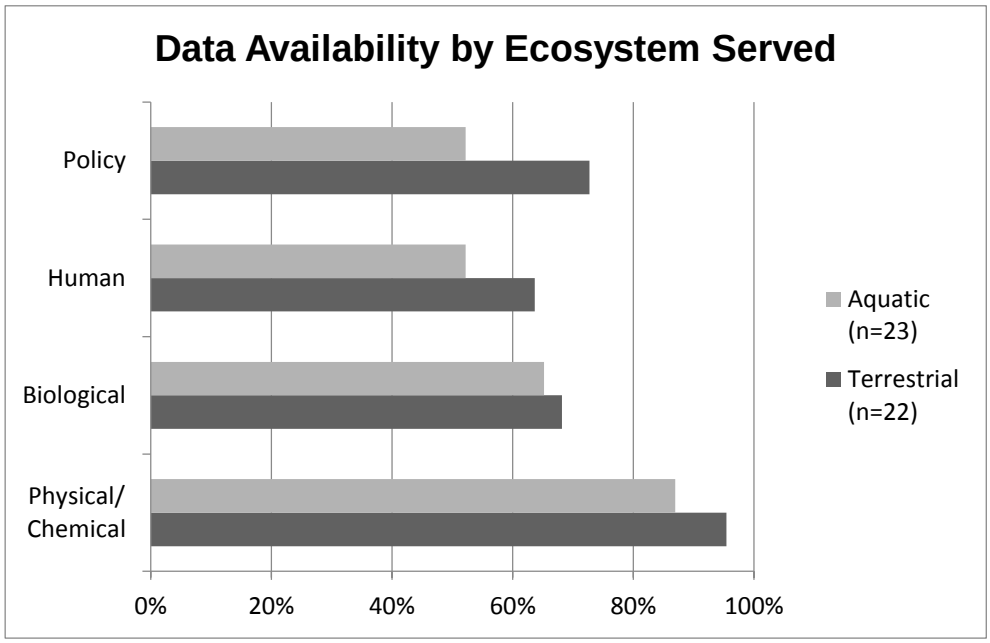

Figure 3. Data availability by ecosystem and type.

Tool Functionality

This subsection summarizes the qualitative variables collected that describe the tools functionality, interfaces, documentation, user support, and other features. Most websites surveyed are best described as information gateways or online mapping resources than decision support systems, in that relatively few offer custom reporting and fewer still include rich analysis, projection, and reporting functionality. The quality and usability of user interfaces varied widely. If further help was needed, documentation was not widely available, and most sites did not offer support beyond a web form or email address. Required plug-ins and unclear data age are some final potential barriers to effective tool use.

<u>Custom Queries</u>

This variable captured any tool functionality beyond zooming, panning, or simple text

searching which relies on user-provided information in order to provide a customized result of some type. The tools can be grouped into three categories. The simplest custom queries allowed users to conduct searches by zooming to specific areas, clicking on the map (probing), or drawing polygons, and in each case viewing information available for that area or point (T4, T26, T39, T30 and T53). The next group allowed users to create customized reports from user-defined buffers and/or polygons (T3, T49, T15). Finally, eight tools allowed users to conduct some type of custom analysis:

- Lakebed Alteration DSS (T12) - Can create a customized suitability map.
- FieldScope (T23) - Can compute watershed and flow path, as well as annotate map with drawing tools. Users can create scatter and time series plots from observation data.
- Pileus Project (T27) - Can run reports for different places on the impact of climate change on tourism and agriculture.
- EnviroAtlas (T50) - Can select a HUC-12 watershed by clicking a single point. Then, the Analyze Ecosystem Services tool estimates 7 dimensions of ecosystem services provided within the watershed. A similar tool estimates the path of a raindrop to the nearest stream.
- Great Lakes Environmental Response (T42) - Can use one or multiple polygons to select features, to calculate NOAA environmental sensitivity index, or to tabulate species appearing in FWS Information, Planning, and Conservation (IPaC) listings
- SPARROW DSS (T18) - Can select specific stream reaches, modify assumptions, and see modeled results for selected pollutants.
- Tipping Point Planner (T17) - Can complete a variety of customized suitability/ranking tasks for a given HUC-12 watershed.
- Data Basin (T41) - With a paid subscription, can use advanced analysis tools including selections, buffer, site analysis, and download to shapefile.

Most of these tools offer simply customized reporting. The few that allow projecting the results of management scenarios--by modeling and comparing scenarios—generally do not deal with Great Lake aquatic ecosystems. One exception to this observation is the Lakebed Alternation DSS (T12).

User Interface

The reviewed tools demonstrated a wide range of usability practices. Because usability

is best assessed through empirical studies with target users, and depends on user knowledge, no systematic assessment was attempted. However, the reviewers found some to be confusing or difficult to use, while others were relatively intuitive. Designers faced trade-offs when selecting icons for map-related tasks, such as zooming, identify, and select. Some relied on icons for these tools used by ESRI's software, which has the advantage of usability for users with GIS experience. Others opted for nonstandard icons, which run the risk of confusing users with GIS experience but may be more usable for a general audience.

Documentation

Many tools have no or minimal documentation. Tools with the most documentation available (including T50, T41, T3) typically included pop-up or easily accessible explanatory web pages, FAQ documents, longer guides or manuals, and/or videos to explain concepts or functionality.

Support Availability

The most common type of support provided was via a form and/or email address (28 tools). Just five provided no support information at all. In addition to email, four offered user support by telephone. It was not possible to evaluate whether the forms and emails were monitored and whether users would receive helpful and timely responses.

Gatekeeping

Most tools did not require registration, permission, or payment in order to gain access. A few require visitors to click "Agree" or otherwise view a disclaimer as to data quality. Only three (T22, T17, T41) required users to complete a free registration for some or all data. Land Information Ontario (T24) provides on a few layers for download, many others require purchase or licensing.

Other Issues

It was not possible to determine the technical details of the tools unless they contained explanatory information, although some relied on ArcGIS server, Google maps, Open Layers, MapBox, and/or Geoserver. Some required Flash or Java plug-ins, which may pose a barrier to some users. Finally, the recency of the data and tool maintenance varied widely but were difficult to assess. Many boasted data less than one year old, including T53, T46, T6, T42, or even real-time data (T26, T22, T19). Four tools (T27, T48, T21, T20) did not provide enough

information for reviewers to be confident that their website or data was actively maintained.

Comparison Tools

The review included 16 comparison tools. This section highlights several features, drawn from these comparison tools as well as the Great Lakes tools, which might be useful for a GLAHF-DSS.

<u>Drawing & Analyzing Areas</u>

Two of the comparison marine spatial planning tools, the Mid-Atlantic Ocean Data Portal (T36) and the Washington Marine Planner (T37) allow users to draw an area, and generate a customized report which features a description of the area within the polygon that has been drawn. For T37, users can draw a proposed area for protection, and generate a report which describes the prevalence of habitat in the area for various species, ocean floor characteristics, and other factors. The tool also supports conducting a simple suitability analysis, and conducting a “trade-off analysis” to compare multiple sites. Designed to facilitate planning for wind energy, users of T36 can run one of several reports after selecting one or more wind energy lease block areas: wind energy potential, distance to coastal substations, distance to AWC Hubs, distance to shore, depth range, and distance to ship routing measures.

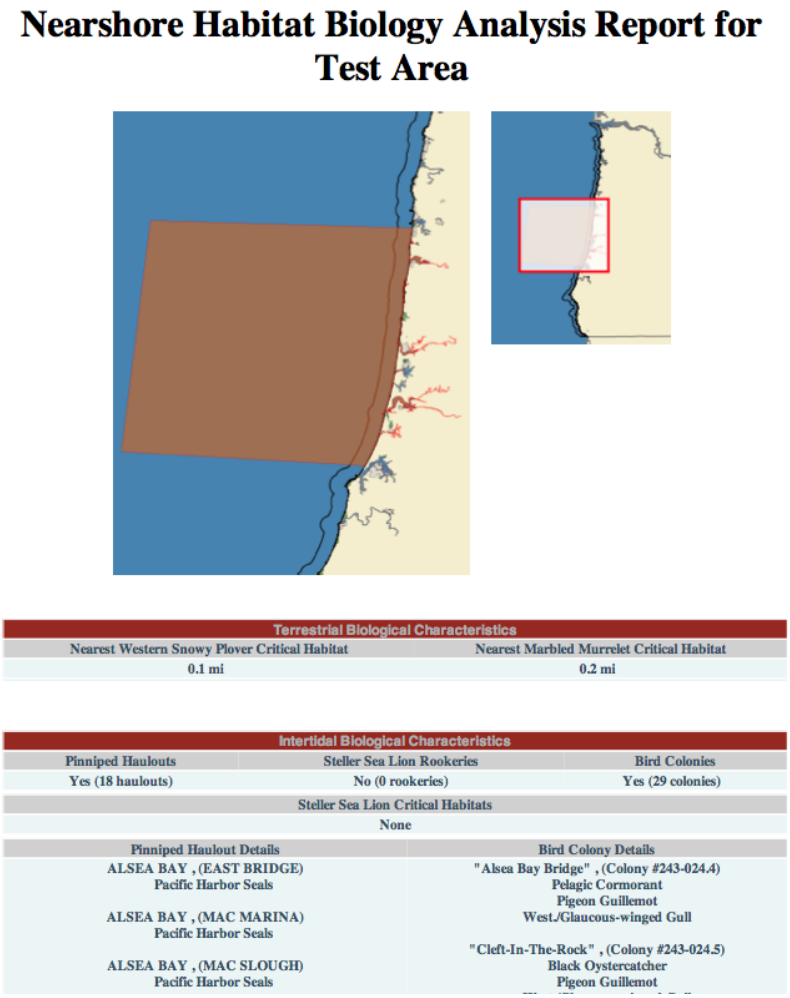

Figure 4. Report produced by Washington Marine Planner (T37).

Problem-Driven Tool

The Pileus Project (T27) features several tools which support structured analysis related to the impacts of climate change on the state of Michigan. The project has created tools facilitating analyzing climate change and the impact on skiing, tourism traffic, and agricultural productivity. As shown above, this includes looking at projected weather trends relevant for agriculture. Although easy to use, tools like this requires the problem be framed in a particular way, and do not support more open-ended data viewing or analysis.

Figure 5. Interface from Pileus Project (T27).

Trend Analysis of Observations and Projections

The Great Lakes Water Level Dashboard (T6) provides access to the single variable of water levels, with limited spatial resolution in its outputs. In the example above, recent observations are overlaid on historical lows and highs, showing very low levels in the upper Lakes over the past five years, with error bars for projected levels extending into the near future. Older historical records and reconstructions, past projections, and multi-decade forecasts are also accessible through this single, intuitive interface. Similar

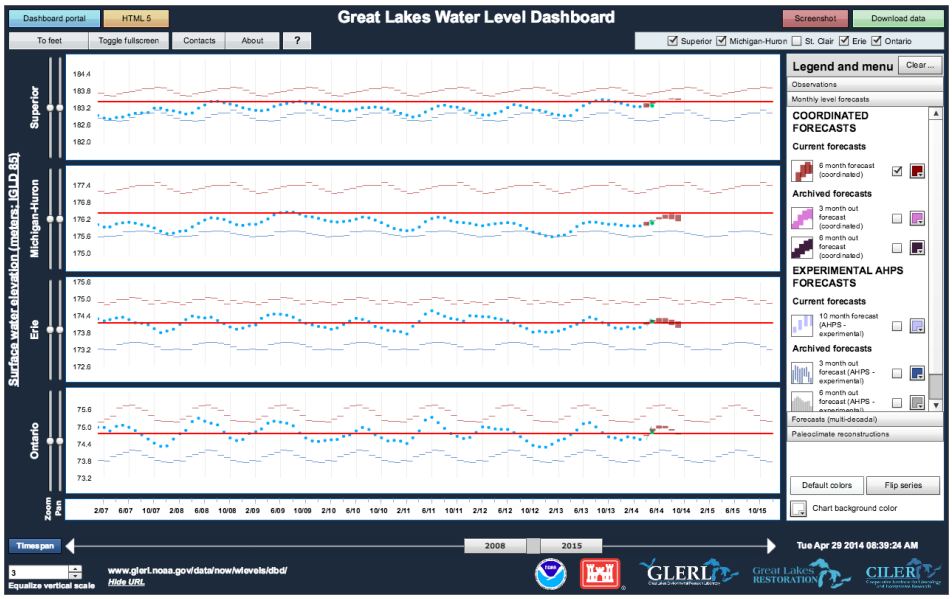

Figure 6. Interface from Great Lakes Water Level Dashboard (T6).

interactive graphs and charts could be added to any map-based tool that provides reporting or projections on a user-specified area.

Metadata: Promoting Discovery of Other Resources

The Great Lakes Information Management and Delivery Service (T1) is a prototype website including descriptions and screenshots for a wide variety of Great Lakes data, mapping services, and other tools. One of its strengths is a highly developed hierarchy of resource categories allowing detailed searches. This approach could fruitfully be applied to wide-ranging databases of content hosted on a single tool's website as well.

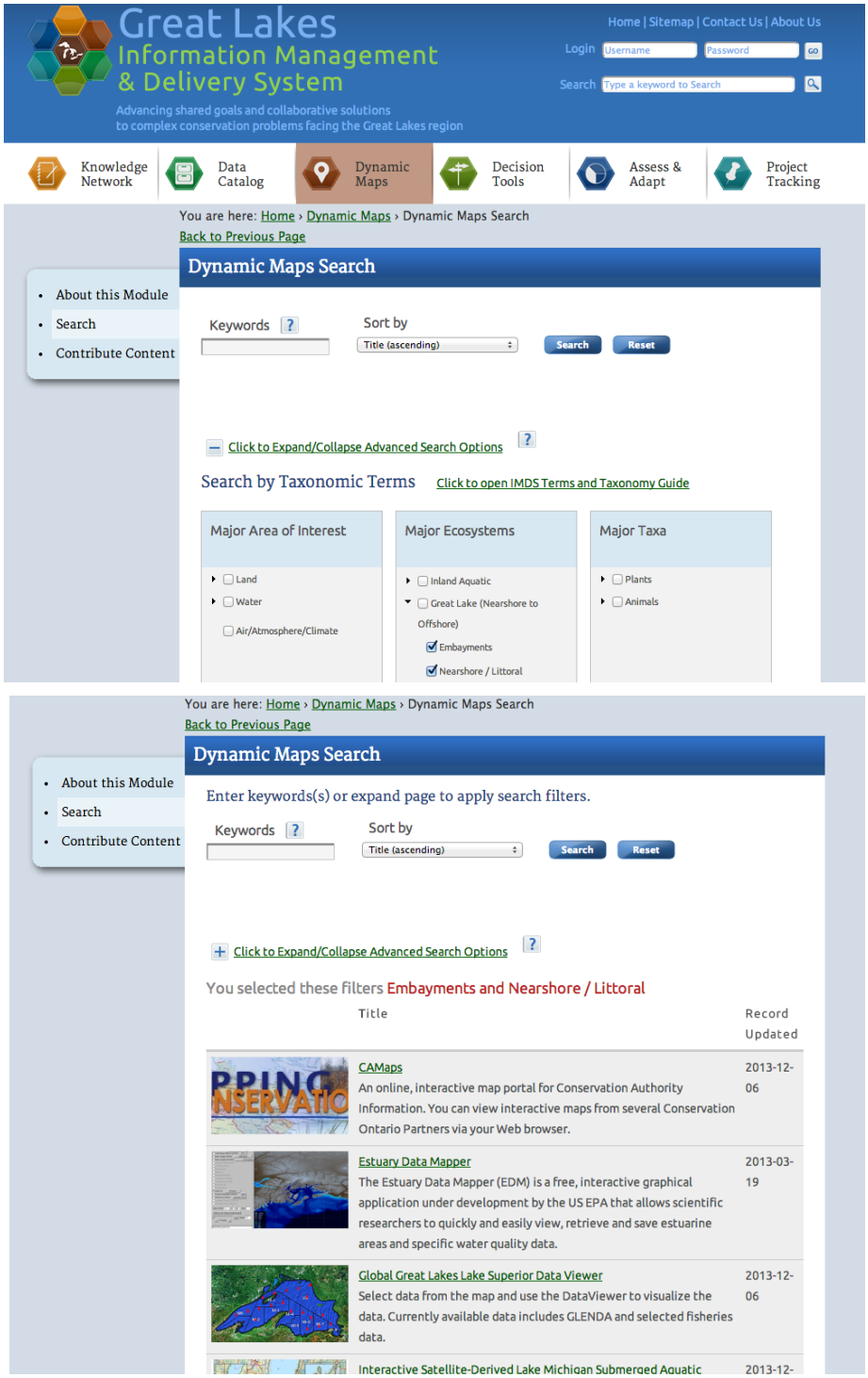

Figure 7. Great Lakes Information Management and Delivery Service (T1).

5. Discussion

This research has identified six gaps across the set of Great Lakes web-based geospatial information tools. This section summarizes each observed gap and then reflects on its importance to Great Lakes ecosystem management and reasons for its existence.

1. Lack of holistic habitat perspective

The idea of ecosystem-based management, or the idea that "the environment ought to be managed in whole ecological or landscape units based on integrative biological, physical, and/or socioeconomic assessments" (Slocombe 1993) has been pursued in the Great Lakes for many years. By its nature, it requires integrating diverse types of information, a focus on ecosystems, and an emphasis on interconnections in the environment. Although making available a wealth of information available to users, few of the geospatial information tools allow for the holistic perspective required for ecosystem-based management. In particular, the review confirmed a need for the habitat classifications that are part of GLAHF. One important issue for ecosystem-based management is the need to align ecosystem and management boundaries. While beyond the scope of this project, the hierarchal nature of GLAHF makes it possible for the GLAHF-DSS to summarize data at multiple scales and to multiple geographic units.

2. Lack of integrated data between aquatic and terrestrial ecosystems, and the coastal margin

In a related issue, few of the tools reviewed integrate data between aquatic and terrestrial ecosystems, and fewer still focused on the coastal margin. Making these connections is important for ecosystem-based management, since there is a need to be able to relate physical, chemical and biological data to classify habitat, prioritize management and restoration, and identify patterns. This gap is understandable since data for aquatic and terrestrial ecosystems come from different sources and are provided at different scales. GLAHF allows for the explicit linking of terrestrial, coastal margin, and aquatic habitat data through a single database framework. Another explanation for this gap is the institutional division between managers working on aquatic and terrestrial ecosystems. GLAHF-DSS can support the growing number of managers interested in exploring these connections further.

3. Relative lack of human activity and policy data

As described above, the most common types of information available was physical or chemical, and only about a half contained policy data. This gap is partly understandable due to

the scientific origins of many of the datasets and tools, which reflect institutional and funding priorities. However, human resource use and activities influence ecosystem function, and are therefore needed alongside physical/chemical and biological data to prioritize areas for clean-up, management, and restoration.

4. Lack of fine-scale data, especially across national boundaries

Fine-scale data, defined by this report as about 30 meters or less, was identified in the interviewees as required in order to make management decisions. However, such data is resource-intensive to collect, process, and publish. Mapping and comparing fine-scale data requires overcoming differing data standards, collection schedules, and data access rules across jurisdictions. Although this is an important gap that GLAHF can address, it should be noted that some managers indicated they needed information at a more detailed spatial resolution. In particular, Coastal Zone Managers reported that 30 meters was too broad for their purposes. It is possible that GLAHF might support finer scales in the future, or these needs might be met with additional tools.

5. Relative lack of downloadable data

Another theme that emerged from the interviews was the complementary relationship between web-based and desktop GIS. Although the informants expressed interest in accessing geospatial information online, they also described existing internal GIS capacity and geospatial data. Therefore, they reported that manipulating data offline is essential, and stated they would rely on online tools for data exploration. As a result, providing downloadable data in spatial data formats is necessary for tools to support not only exploration, but also detailed mapping and analysis using desktop GIS software. Unfortunately only 62% of the tools reviewed offered data for download. There are many explanations for this, including policies and legal constraints to sharing, concerns about data use and interpretation, or technical barriers that make hosting data downloads difficult.

6. Lack of tools offering analysis and prediction

The final, and potentially most difficult, gap to fill is the need for tools that provide analysis and prediction. The interviewees reported that many management tasks require data analysis to test the possible effects of changes, and support decision making. They stated a desire for tools that would provide accurate predictions of the effects of specific, discrete actions, such as developing a specific parcel or granting a specific permit. Providing tools for such analysis is difficult, given the highly variable nature of these analyses. More seriously,

limitations to scientific knowledge may make such analysis difficult or impossible. Most of the tools reviewed are designed to facilitate read-only access to spatial information, with limited ability to conduct customized analysis.

6. Conclusion

In order to inform the development of a new geospatial information tool for Great Lakes ecosystem-based management, this report describes the results of a key informant interviews as well as a systematic review of 37 web-based spatial information tools. Drawing from these two sources, we identified six gaps in these existing tools, many of which can be addressed by the design of a new tool that takes advantage of the existing ingredients of GLAHF (database framework, fine-scale database, habitat typology).

However the interviews and limited literature review paint a sobering picture about the potential for web-based tools to inform policy. The informants we spoke with mentioned only a few of the tools by name. Although this may partly be due to their managerial roles (versus as data analysts or front-line managers), it may also be explained by the mismatch observed between the existing tools and what managers need. For example, many existing tools focus on narrow topics, do not provide for data downloads, or do not contain sufficient spatial resolution for data users. However, these choices reflect understandable limitations in data availability, and also the tradeoff that exists between complexity and usability.

This finding points to the need for close collaboration between tool developers, the scientific community, and managers and policymakers. In the short term, adopting a participatory design method for the GLAHF-DSS will help translate the gaps identified in this report into concrete ideas which can be implemented as new tools. However the findings also point to the importance of ongoing dialog and communication between the GLAHF-DSS project and a user community.

Appendices

Appendix A. Great Lakes Web-Based Geospatial Information Tools
Appendix B. Additional Web-Based Geospatial Information Tools
Appendix C. Tool Review Variables

Appendix A. Great Lakes Web-Based Geospatial Information Tools

ID	Tool Name	Category	URL	Creator	Description	Extent	Nation(s)
T1	Great Lakes Information Management & Delivery System (IMDS)	Education/Information Access	http://imds.greenlitestaging.com/	TNC, USGS, and the Upper Midwest & Great Lakes Landscape Conservation Cooperative (UMGL LCC)	The Great Lakes IMDB is an integrated set of websites designed to facilitate the development and sharing of data, knowledge, and information to support strategic conservation of the Great Lakes.	GL basin	Both
T3	GeoWebFace	Management	https://www.michigan.gov/deq/0,4561,7-135-3311_60700---,00.html	Michigan DEQ, Office of Oil, Gas, and Minerals	The free GeoWebFace provides a wide array of geologic information for natural resource management, educational and general interests.	State/Province	U.S.
T4	Science in the Great Lakes Mapper (previously "Lakewide Management Plans Mapper")	Management	http://wim.usgs.gov/sigl/siglmapper.html	USGS-WI	SiGL is a Web Mapping Application to display information about monitoring projects and programs around the Great Lakes.	GL basin	Both
T5	National Fish Habitat Partnership Data System	Management	http://ecosystems.usgs.gov/fishhabitat/	NFHP with assistance from USGS	The NFHP Data System provides users with enhanced data access and online map browsing of detailed information for fish habitats nationally.	Country-wide	U.S.

T6	Great Lakes Water Level Dashboard	Management	http://www.glerl.noaa.gov/data/now/wlevels/dbd/	NOAA-GLERL	The GLWLD displays time-series of measured monthly and annual water level data and seasonal forecasts for each of the Great Lakes, reconstructed lake levels from paleoclimate research, and decadal lake level projections under alternative climate scenarios.	GL basin	Both
T8	Great Lakes Environment Assessment and Mapping Project (GLEAM)	Management	http://greatlakesmapping.org/	GLEAM	GLEAM provides maps to visualize and understand environmental impacts (or stressors) on the lakes and benefits humans enjoy from the lakes (or ecosystem services).	GL basin	Both
T9	Wisconsin Coastal Atlas	Management	http://www.wicoastalatlas.net	Wisconsin SeaGrant	The Wisconsin Coastal Atlas helps people better understand coastal issues, share coastal data, and inform decision-making about sustainable use of the Great Lakes. The atlas serves as a gateway to decision support tools relevant to Great Lakes management and provides access to educational resources about coastal issues in Wisconsin.	State/Province (WI)	U.S.
T10	Ohio Coastal Atlas - Interactive Coastal Atlas	Management	http://ohiodnr.com/OhioCoastalAtlasProject/InteractiveAtlas/tabid/23428/Default.aspx	Ohio DNR	The Interactive Coastal Atlas Map Viewer is a web-based mapping resource that allows users to manipulate and view a variety of geospatial data layers as well as create and print customized Ohio Coastal Atlas maps. The ICA Map Viewer 2.0 integrates many topic-specific 'use-case' data layers, including Lake Erie Environment and the Lake Erie Watershed.	State/Province (OH)	U.S.
T11	USACE Oblique Image Viewer	Management	http://greatlakes.usace.army.mil/	US Army Corps of Engineers	Great Lakes Oblique Imagery [no further description available]	GL basin	U.S.

T12	Lakebed Alteration Decision Support Tool (LADST)	Management/ Planning	http://glgis.org/ladst/	NOAA-GLERL and U-M/Michigan DNR Institute for Fisheries Research	The system assists resource managers in making siting decisions for lakebed-altering projects in the Great Lakes, by allowing them to create their own suitability maps based on criteria of their choosing.	GL basin	Both
T13	GLRI Phragmites DST Mapper	Management/ Planning	http://cida.usgs.gov/glri/phragmites/	USGS	The GLRI Phragmites Decision Support Tool (DST) Mapper is intended to provide resource managers with information to strategically develop effective Phragmites control and invasion prevention programs in the Great Lakes coastal zone (10 km inland from the shoreline).	GL basin	U.S.
T14	Great Lakes Nonindigenous Species Information System (GLANSIS)	Management/ Planning	http://www.glerl.noaa.gov/res/Programs/glansis/glansis.html	NOAA-GLERL	A database documenting aquatic non-indigenous species observed in, or likely to invade, the Great Lakes.	GL basin	U.S.
T15	Climate Wizard	Management/ Planning	http://www.climatewizard.org/	TNC	ClimateWizard enables technical and non-technical audiences alike to access leading climate change information and visualize the impacts anywhere on Earth. Users can assess how climate has changed over time and can project what future changes are predicted to occur in a given area.	Country-wide	U.S.
T16	SeaSketch - Great Lakes Wind Collaborative Prototype	Management/ Planning	http://www.seasketch.org/#projecthomepage/50a6ad147fb51a603d03feae/about	GL Wind Collaborative et al.	The Great Lakes Regional Wind Siting prototype is designed to provide information and data related to environmental, economic and social impacts of wind energy, as well as tools to inform decision-making on the siting of large-scale renewable energy projects.	GL basin	U.S.

T17	Tipping Point Planner	Management/ Planning	http://www.tippingpointplanner.org	Purdue & Illinois Sea Grant	Tipping Points and Indicators is a Great Lakes research and extension program comprised of a web-based decision support system and facilitated community action planning process for a local watershed, using tipping points, or thresholds.	GL basin	U.S.
T18	SPARROW Decision Support System	Management/ Planning	http://cida.usgs.gov/sparrow/#region=MI:modelid=41	USGS	The SPARROW Decision Support System (SPARROW DSS) provides access to national, regional, and basin-wide SPARROW models (Spatially Referenced Regressions On Watershed attributes). For each model, users can map predictions of water quality, track transport to downstream waters, evaluate management scenarios, and overlay reference data.	Country-wide (Includes Upper Midwest Model)	U.S.
T19	Great Lakes Observing System (GLOS) Data & Tool Portal	Research	http://glos.us/data-access/data-portal	GLOS	The GLOS Data Portal provides access to near-realtime and archived observations and to model forecasts for the Great Lakes. This includes lake conditions, water levels, wave heights, air and water temperatures and more.	GL basin	Both
T20	Great Lakes Information Network - GIS features (Map Builder portal and data portal)	Research	http://gis.glin.net/	GLC	The GLIN Maps and GIS website provides a centralized location to discover, publish, and acquire geospatial data for areas within the Great Lakes region.	GL basin	Both
T21	Great Lakes Monitoring	Research	http://greatlakesmonitoring.org/	IL/IN Sea Grant	This site provides easy access to environmental monitoring data collected by various sources throughout the Great Lakes.	GL basin	Both

T22	Great Lakes CoastWatch	Research	http://coastwatch.glerl.noaa.gov/	NOAA-GLERL	Serving as the Great Lakes node of the national CoastWatch program, GLERL obtains, produces, and delivers environmental data and products for near real-time observation of the Great Lakes to support environmental science, decision making, and supporting research.	GL basin	Both
T23	FieldScope	Education/Information Access	http://greatlakes.fieldscope.org/	NatGeo, USGS, GLOS	Great Lakes FieldScope is a web-based mapping, analysis and collaboration tool for formal and non-formal educators that engages students and volunteers as citizen scientists.	GL basin	Both
T24	Land Information Ontario	Education/Information Access	http://www.mnr.gov.on.ca/en/Business/LIO/index.html	OMNR	Land Information Ontario (LIO) manages key provincial datasets and collects high resolution satellite imagery. LIO makes these and hundreds of other data sets available to registered users, most of them at no charge.	GL basin	Can.
T25	Open Data Ontario	Education/Information Access	http://www.ontario.ca/government/open-data-ontario	Ontario	Open data catalogue [no further description available]	GL basin	Can.
T26	Great Lakes Coastal Forecasting System	Research	http://www.glerl.noaa.gov/res/glcfs/	NOAA-GLERL	GLCFS is a system of computerized models that can simulate and predict the three-dimensional structure of currents, temperatures, water level fluctuations, wind waves, ice, and sediments in the Great Lakes.	GL basin	Both
T27	Pileus Project	Management/ Planning	http://pileus.msu.edu/	MSU Research Group	The overarching purpose of the Pileus Project is to provide useful climate information to assist decision makers. The current focus is on two leading industries in the Great Lakes region: agriculture and tourism.	State/Province	U.S.

T30	NOAA Digital Coast data access viewer	Data Portals	http://www.csc.noaa.gov/dataviewer/	NOAA	This NOAA-sponsored website is focused on helping communities address coastal issues. The Digital Coast provides coastal data from reputable sources and the all-important tools, training, and information needed to make these data truly useful.	Country-wide	U.S.
T31	The National Map viewer	Data Portals	http://nationalmap.gov/viewer.html	USGS	Use The National Map Viewer and Download Platform to visualize, inspect, and download our most current topographic base map data and products.	Country-wide	U.S.
T39	Marine Cadastre	Management	http://csc.noaa.gov/mmcviewer/	NOAA	This data viewer provides the baseline information needed for ocean planning efforts, particularly those that involve finding the best location for renewable energy projects. It displays applicable jurisdictional boundaries, restricted areas, laws, critical habitat locations, and other important features.	Country-wide	U.S.
T41	Data Basin	Data Portals	http://databasin.org/	Conservation Biology Institute	Data Basin is a science-based mapping and analysis platform that supports learning, research, and sustainable environmental stewardship	Country-wide	U.S.

T42	Great Lakes Environmental Response	Management/ Planning	https://www.erma.unh.edu/ greatlakes/	NOAA, Office of Response and Restoration	ERMA integrates and synthesizes various real-time and static datasets into a single interactive map, thus providing fast visualization of the situation and improving communication and coordination among emergency responders and environmental resource managers.	GL basin	U.S.
T46	NOAA View Data Imagery Portal	Education/Information Access	http://www.nnvl.noaa.gov/view/	National Oceanographic and Atmospheric Administration, Environmental Visualization Laboratory	NOAA View provides access to maps of NOAA data from a variety of satellite, model, and other analysis sources.	Country-wide	Both
T48	Global Great Lakes - Laurentian Great Lakes tools	Research	http://globalgreatlakes.org/lgl/superior/	University of Minnesota-Duluth	A web-based system of data acquisition, database management, decision support modeling and informative visualization to enable anticipatory management of the world's great lakes. Lake Superior has been selected as the prototype for this project	Single Lake (Superior)	Both
T49	Environmental Data Discovery and Transformation (EnDDaT)	Research	http://cida.usgs.gov/enddat/	USGS Center for Integrated Data Analytics	EnDDaT is a tool used to discover and export data from our natural environment. This tool accesses data from a variety of data sources, compiles and processes the data, and performs common transformations.	GL basin	U.S.
T50	EnviroAtlas	Data Portals	http://enviroatlas.epa.gov/enviroatlas/atlas.html	USEPA	EnviroAtlas is a collection of interactive tools and resources that allows users to explore the many benefits people receive from nature, often referred to as ecosystem services.	Country-wide	U.S.

T51	Water Withdrawal Assessment Tool	Management/ Planning	http://www.miwwat.org/	Michigan DNR/IFR	The Water Withdrawal Assessment Tool (WWAT) is designed to estimate the likely impact of a water withdrawal on the habitat health of nearby streams and rivers.	State/Province	U.S.
T52	FishVis	Management/ Planning	http://wimcloud.usgs.gov/apps/FishVisDev/FishVis.html	USGS	[No description found]	GL basin	U.S.
T53	GEO Great Lakes Metadata Catalog	Data Portals	http://slrfvm.glos.us/geonetwork/srv/eng/main.home	GLOS, GLIN, and multiple partner agencies	Contains information about geographically referenced data for the Great Lakes region, allowing users to identify useful maps, datasets and other information products and find out how to obtain them.	GL basin	Both

Appendix B. Additional Web-Based Geospatial Information Tools

ID	Tool Name	Category	URL	Creator	Description
T2	Great Lakes Restoration Database	Management	http://habitat.glc.org/	GLRI/GLC	The Great Lakes Restoration Database (GLRD) is a searchable database of projects implemented under the Great Lake Restoration Initiative's Habitat and Wildlife Protection and Restoration Focus Area.
T28	USGS Nonindigenous Aquatic Species (NAS)	Management/Planning	http://nas.er.usgs.gov/	USGS	Provides scientific reports, online/realtime queries, spatial data sets, regional contact lists, and general information regarding Nonindigenous Aquatic Species.
T29	Critical Habitat Mapper	Other	http://fpdss.fws.gov/critha b/	FWS	The online service for information regarding Threatened and Endangered Species final Critical Habitat designation across the United States.
T32	SeaSketch	Comparison Tools - US MSP	http://www.seasketch.org	UCSB, ESRI, New Zealand	SeaSketch supports collaborative planning for our oceans, allowing users to easily generate alternative proposals representing a range of perspectives and interests, and to receive analytical feedback within seconds.
T33	Madrona	Comparison Tools - US MSP	http://madrona.ecotrust.org	EcoTrust	Madrona offers a flexible set of software building blocks for creating cutting-edge tools for decision support and area-based planning that can be used by a broad audience.
T35	Community-Focused Exposure and Risk Screening Tool (C-FERST)	Other	http://cfpub.epa.gov/cferst/	USEPA	C-FERST is a web-based "toolkit" providing access to science for community decision-making. Its tools assist with identification and prioritization of community environmental health issues.

T36	Mid-Atlantic Ocean Data Portal	Comparison Tools - US MSP	http://portal.midatlanticocean.org/portal/	Mid-Atlantic Regional Council on the Ocean (MARCO)	The MARCO Portal is an online toolkit and resource center that consolidates available data and enables state, federal and local users to visualize and analyze ocean resources and human use information.
T37	Washington Marine Planner	Comparison Tools - US MSP	http://washington.marineplanning.org/	MarineMap/ Washington	The Washington Marine Planner is a pilot project intended to support the state's Marine Spatial Planning (MSP) process and the Pacific County Shoreline Master Plan (SMP) data and inventory characterization.
T38	Oregon MarineMap	Comparison Tools - US MSP	http://oregon.marinemap.org/	MarineMap/ Oregon	Oregon MarineMap will facilitate the positioning of nearshore marine habitats and renewable ocean energy sites through visualization, analysis, and collaboration.
T40	Northeast Ocean Data Portal/Viewer	Comparison Tools - US MSP	http://www.northeastoceandata.org/	The Northeast Ocean Working Group	Maps and data for ocean planning in the northeastern United States
T43	Ontario Fish ON-Line	Other	http://www.web2.mnr.gov.on.ca/fish_online/fishing/fishingExplorer_en.html	Ontario MNR	Fish ON-Line provides fish species and fishing regulation information to new and experienced anglers.
T44	Ontario MNR Renewable Energy Atlas	Other	http://www.giscoeapp.lrc.gov.on.ca/web/MNR/Integration/Renewable/Viewer/Viewer.html	Ontario MNR	The Renewable Energy Atlas is an interactive tool that gives Ontarians the ability to electronically view wind and water renewable energy resources in the province.

T45	Great Lakes Information Network - News, Tourism, and Teaching sections	Other	http://www.glin.net	GLIN	The Great Lakes Information Network (GLIN) is a partnership that provides one place online for people to find information relating to the binational Great Lakes-St. Lawrence region of North America. GLIN offers a wealth of data and information about the region's environment, economy, tourism, education and more.
T47	SSEC RealEarth Map Server	Other	http://wms.ssec.wisc.edu/	University of Wisconsin-Madison, Space Science and Engineering Center	[No description available]

Appendix C: Tool Review Variables

Purpose:
Choose one, representing the primary purpose/audience:

- Management
- Management/Planning (problem-specific)
- Research
- Educational/Information Access
- Comparison (national tools and generic platforms)

Domain of data represented:
Choose all that apply:

- Physical/Chemical (including topobathymetry, geomorphology, energy, hydrology, imagery)
- Biological (including wetlands, habitat conditions)
- Human activity (including land use, shoreline modification, economic)
- Policy/planning (including areas of concern)

Spatial scale and extent:

- Extent, *choose largest that applies:*
    - Great Lakes basin
    - Multi-state region
    - State/Province
    - Sub-State/Province
    - Country-wide
    - Outside Great Lakes
- Scale of analysis, *choose all scales that the tool operates effectively for:*
    - parcel (data resolution approx <=50x50m)
    - county/district (data resolution approx <= 2x2km)
    - lake/basin (data resolution approx > 2x2km)
- Nations*:*
    - Binational vs. U.S. only vs. Canada only
- Zones, *choose all that apply:*
    - Watershed,
    - Coastal Terrestrial,
    - Coastal Margin,
    - Coastal Nearshore,
    - Offshore

Data availability:

- Output formats, *choose all that apply:*
    - Maps
    - Graphs
    - Tabular data (on-screen)
    - Downloads
    - Links to others' data
- Data sources:
    - Self-generated (organization's own data) *(y/n)*
    - Outside source(s) *(list one outside source, or "multiple")*
- Gatekeeping:
    - Does the organization require registration, permission, or a license to access data? *(describe, or n/a)*

Technical Functionality

- Does the tool perform computations based on user input? *(describe, or n/a)*
    - *(user input might include polygons, inputs to a model/forecast, or weightings for combining layers)*
- Description of technical architecture as best as can be determined (e.g., ArcGIS server application, ArcIMS application, interactive website, etc.)
    - Server-side:
    - Client-side:
        - Are special plug-ins needed?

Usability:

- How complex is the user interface? How well are user interface standards met? *(free-form text; may develop measures later)*
- Is documentation present? *(y/n, describe coverage)*
- Is support available? *(y/n, describe mechanism)*

Maintenance:

- Freshness of data - how old is the tool's dataset? *(year/date of newest data)*
- Are there signs the site has not been maintained for a period of time?

Evaluation:

- Strengths of tool
- Weaknesses of tool

Works Cited

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