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Eanes, F., J.M. Silbernagel, D.A. Hart, P. Robinson, and M. Axler. (2018). Participatory mobile- and web-based tools for eliciting landscape knowledge and perspectives: introducing and evaluating the Wisconsin Geotools Project. Submitted to Journal of Coastal Conservation. 1-18; doi: 10.1007/s11852-017-0589-2

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Participatory mobile- and web-based tools for eliciting landscape knowledge and perspectives: introducing and evaluating the Wisconsin Geotools Project

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Abstract:

Purpose: Despite synergistic goals across a wide breadth of fields and modalities, coastal landscape conservation projects that engage the lay public and integrate narratives of place remain elusive. This paper addresses these needs by introducing and evaluating the Wisconsin Geotools, an integrated pair of mobile-and web-based applications that allow users to generate and share spatially defined multimedia observations — including photos, short textual descriptions (or journals), and audio and video clips — of their surrounding bioregional landscapes.

Methods: We followed a participatory, user-centered design process to develop a mobile application that uses GPS capabilities to geolocate multimedia observations of landscapes and feed them into a web-based application, which displays content through the structure of an interactive story map. The applications were piloted with coastal community user groups in Green Bay (Lake Michigan), Wisconsin, USA.

Results: Over 800 observations were recorded by participants in our study area. Results from a user evaluation survey indicate the geotools effectively engaged participants in learning about and exploring their surrounding coastal landscapes. A spatial analysis revealed participants' affinity for water-related features in landscapes.

Conclusions: We close by suggesting a variety of ways in which these tools can support future projects and existing methodologies that are advancing transdisciplinary approaches to engaging the public in coastal conservation.

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1. INTRODUCTION

Dominant paradigms of landscape research and design continue to shift towards place- and solution-driven approaches (Wu, 2006), with an increasing emphasis on conceptualizing landscapes as social-ecological systems that provide critical ecosystem services (Daily et al., 2009; Cumming et al., 2013; Wu, 2013). Concomitant with this paradigmatic shift towards landscape sustainability and resilience is a recognition that successfully designing and implementing alternative landscapes depends upon transdisciplinary participation and multiple modes of knowledge production (Kates et al., 2001; Tress and Tress, 2001; Blackstock and Carter, 2007; Seager, 2008). Musacchio (2009: 997) has called for translational landscape research and practice (TLRP) that serves as a bridge between basic research and applied practice — an approach that encompasses "solution-driven projects and activities that are motivated by questions about the systemic relationships among landscape sustainability, people's contact with nature, and complex place-based problems." Achieving truly sustainable and resilient landscapes, according to TLRP, requires an integrative understanding of landscapes, which investigates how varying land uses and landscape patterns affect human perceptions, ecological literacy, and place-awareness.

But while these translational approaches to understanding landscapes' social-ecological and patterns have emerged from traditions in the fields landscape ecology and landscape architecture — e.g. holistic landscape ecology (Naveh, 2000) and bioregionalism (Thayer, 2003), respectively — various social and geographic disciplines share complementary goals. Immersively engaging individuals and communities in "reading" and responding to their surrounding landscapes (Meine, 1999), after all, remains a fundamental (if not explicit) goal of most place-based and environmental educational initiatives (Gruenewald, 2003; Krasny and Dillon, 2013; Roth, 1992; Kudryavtsev et al., 2012). Geoliteracy and geoawareness, moreover, are among the central learning objectives within contemporary geographic education (Kerski, 2015; Gersmehl and Gersmehl 2006, LeVasseur 2005). And understanding human connections to landscapes — whether in built or natural, or high- or mixed-amenity settings — remains a lively area of focus within the many fields that investigate how people's sense of place impacts their environmental behavior, including disciplines such as environmental psychology, conservation psychology, environmental sociology, human geography, human ecology, and tourism and leisure studies (Lewicka, 2011; Trentelman, 2009).

Despite these synergistic goals and shared priorities across the aforementioned disciplines, sustainable landscape design projects that engage the lay public *and* integrate social and ecological components remain elusive (Lang et al., 2012; Velasco et al., 2015). Differences in epistemologies, data, and methodologies complicate this challenge of integration within the research community itself — an effect that is often amplified in efforts that include non-scientists (Ostrom, 2009; DeLyser and Sui, 2014; Hertz and Schluter, 2015). Attitudinal and values-oriented data that focus on social and cultural dimensions of landscapes, for example, do not seem readily compatible with ecologically-oriented approaches that emphasize the dynamics of ecosystem form, function and change. Integrative spatial approaches, such as efforts to map landscape values (e.g. Brown 2005; Brown, 2015) or cultural ecosystem services (e.g. Chan et al., 2012), have made considerable advances toward the goal of collecting and analyzing sociocultural data in a format that is compatible with ecological, non-human components of landscapes. But despite this laudable progress, there is still a need for tools and approaches that facilitate transdisciplinarity knowledge production, promote shared encounters with actual landscapes, and deepen place-conscious learning.

This paper begins to address these needs by introducing and evaluating the Wisconsin Geotools, an integrated pair of mobile-and web-based applications that allow users to generate and share spatially defined multimedia observations — including photos, short textual descriptions (or notes), and audio and video clips — of their surrounding bioregional landscapes. The mobile application uses the mobile phone's GPS capabilities to geolocate each observation and feed it into the web-based application, which displays content through the structure of an interactive story map. Overall, our aim was to create a dynamic platform that promoted among our users a deeper exploration of place and its underlying social-ecological complexities. More specifically, our objectives were to create tools that have the capability to:

1) facilitate human-landscape interactions, spatial literacy, and immersive learning experiences, both in traditional learning spaces (e.g. classroom, office) and outdoor landscape encounters; and
2) allow information-sharing, data analysis, and mutual learning among citizens and landscape scientists/practitioners.

In this paper, we describe the participatory, user-centered design process used to develop the geotools, and demonstrate their capabilities by analyzing the content and user experiences that emerged while piloting the geotools with community partners. We close by suggesting a variety of ways in which these tools can support future projects and existing methodologies that are advancing the transdisciplinary research agenda.

2. BACKGROUND

This project and its resulting geotools reflect a convergence of broad trends in geotechnology, methods in geography and geographic information science, and public participation and learning. On the one hand, the digital revolution continues to create an ever-increasing number of platforms, tools, and methods that have the potential to democratize the production and dissemination of a tremendous variety of place-based knowledge (Goodchild, 2007; Sui and Goodchild, 2011). Increasing ubiquity of smartphones and rapid advancements of the geospatial web combine a host of capabilities — e.g. open-source and/or interactive design templates, location awareness, customizable data visualization interfaces — within approaches to user engagement that prioritize participation, user empowerment, and the collaborative crowd-sourcing potential of web 2.0 (Sui 2015). Platforms like OpenStreetMaps and its mobile corollary Maps.me exemplify advances in the collection and display of user-generated content, particularly volunteered geographic information (VGI) (Goodchild, 2007).

These tools and applications, though, build on long-established qualitative methods in a variety of participatory research traditions. Alt.GIS approaches (Sui, 2015) like participatory photo mapping (Dennis et al., 2009), public participation geographic information systems (GIS) (Sieber, 2006; Elwood, 2006), qualitative GIS (Kwan, 2002) and feminist GIS (Pavlovskaya and Martin, 2007) have a rich tradition of critically interrogating matters of access and knowledge production in traditional GIS platforms and methods (Sui, 2015). A number of aspatial approaches to engaging and analyzing people's place-based perspectives have emerged as well. Visitor-employed photography (Haywood, 1990) and resident-employed photography (Stedman et al., 2004) have been used extensively in leisure and tourism research to help identify specifically meaningful or important places, while photo-elicitation techniques (e.g. photo-voice) are used in interview-based research settings to spark deeper, place-based insights among participants (Balomenou and Garrod, 2010).

At the same time, mobile learning (m-learning) and computer-supported collaborative learning (CSCL) continue to gain traction in the environmental education sciences (Tan et al., 2007). In a recent survey of leading environmental educational researchers and practitioners, Ardoin et al. (2013) noted that 93% of respondents considered the rise of social media and its related mobile technologies to be a high-impact trend with respect to sustainability and environmental learning outcomes. They also identified the need for greater collaborative learning and community engagement opportunities, and suggested that m-learning and CSCL efforts could support those goals. Greenwood and Hougham (2015), similarly, argue that digital geospatial and media tools could play a significant pedagogical role in developing the sorts of place-conscious skills — e.g. environmental observation, care, and sensory experiences — that are central to place-based environmental education. Others, however, link people's (especially children's) increasing screen time to phenomena like nature deficit disorder (Louv, 2008), and as a result have adopted an unapologetically critical stance towards technology in environmental education (e.g. Athman and Bates, 1998; Payne, 2003). Bowers (2006), moreover, argues that place-consciousness and place literacy demand direct experiences and contact with nature, which are distorted by any sort of digital mediation.

Finally, the geotools described herein are an outgrowth of theoretical and applied work on interactive deep maps and spatial narratives. Conceptually proposed as a means for digitally combining qualitative and experiential essence(s) of *place* with the quantitative capabilities of cartesian *space*, interactive deep maps spatially organize multimedia, multi-temporal perspectives of a place, while spatial narratives strategically link whole sets of content (e.g. artistic observations, sensory/experiential perspectives), acting as a sort of connective tissue (Eanes et al., *in review*). Intrigued by the rise of ESRI Story Maps, and drawing on emerging research in interactive cartography and human cognition, Eanes et al. (*in review*) have argued that digital, interactive deep maps and spatial narratives constitute a translational and educational vehicle for conveying social-ecological complexity to various audiences. One example, "The Stories and Science of the St. Louis River Estuary" (http://stlouisriverestuary.org/), uses an interactive deep map and complementary spatial narratives to spatially connect the history, arts, ecology, political issues, and people at the mouth of western Lake Superior's St. Louis River (Silbernagel et al., 2015). The deep map and narratives have been used in workshop settings by regional elementary school teachers and outreach educators to "facilitate science-based discussion and place-based learning regarding coastal issues and resources" (Silbernagel et al., 2015: 197).

For all of their strengths, however, most of the current educational tools and participatory approaches are still largely researcher-driven, may or may not involve end-users in their design and development, and do not always allow participants to interact with one another — whether in real-time or virtually through exposure to other participants' contributions. Like other participatory, open-access platforms like Wikipedia, issues related to content accuracy and moderation are not trivial. Questions also remain with regard to the viability of mobile technology in rural settings with poor cellular connectivity, ownership of data, and participant access to devices (e.g. smartphones) required to run applications of interest. Particularly in regards to our geotools applications, we were interested in whether or not rich, place-based narratives could emerge strictly from user contributions, or if additional interventions — in the form of back-end design and moderation — would be required. Additionally, in recognizing the ambivalence towards technology within the environmental education community (Greenwood and Hougham, 2015) we were curious about how mobile and web geotools might affect people's encounters with actual landscapes. And finally, in light of our project's participatory goals, we were interested in evaluating the effects of prioritizing user input throughout the geotools' design and deployment processes.

3. METHODS

In accordance with our objectives to create a transdisciplinary platform capable of place-based inquiry, this geotools project included three phases: (1) application prototype development; (2) a participatory user-centered design process to iteratively test and improve the geotools; and (3) piloting of the geotools with select community user groups in order to evaluate the applications' capabilities and user experience. Phases (2) and (3) were conducted with participants in the lower Fox River Valley (FRV), a lacustrine and glacial till plains bioregion in northeastern Wisconsin that includes the city of Green Bay and its surrounding communities (Figure 1). The area, which encompasses the southern part of the bay of Green Bay (western Lake Michigan) as well as estuarine and protected wetland habitat, is one of the most biologically diverse in the upper midwest and among the Wisconsin Dept. of Natural Resource's "Legacy Places." At the same time, the FRV continues to suffer from significant water quality challenges due to its industrial past and recent agricultural intensification in the watershed, resulting in bioaccumulation of heavy metals (e.g. PCBs), aquatic invasive species infestation, regular harmful algal blooms, and an ongoing listing as a Great Lakes Area of Concern (Karasov, 2005; Brazner, 1998; Vander Zanden, 2008; Klump, 2014). Given these challenges, a recent regional needs assessment report identified as the highest

Figure 1. Study area of northeast Wisconsin and its constituent bioregions. Map adapted from US EPA.

priority the need to "foster and increase partnerships, citizen involvement, and sense of place related to freshwater estuaries" and "increase basic knowledge and awareness related to freshwater estuaries"

(Robinson and Shepard, 2011: 8). The complexity of the FRV and its surrounding bioregions make northeastern Wisconsin the sort of mixed-amenity place ideal for addressing this need through a transdisciplinary and participatory project such as ours.

3.1 Application Prototype Development

The first phase of the study, completed between September 2012 and December 2013, consisted of developing geotools prototypes. Members of the project team initially spent two weeks working with ESRI's Applications Prototype Laboratory to co-design the foundation of the geotools platform. Using ESRI's ArcGIS.com as a backbone, the mobile and web applications allow simultaneous, real-time uploading of geotagged multimedia content in the form of photos, text, audio, and video. Content is associated with and filtered through a nested hierarchical structure (Figure 2) that consists of places, topics, sites, and clusters of observations. In this nested hierarchy, any given place (e.g. Green Bay) contains multiple topics (e.g. UWGB Ecology Class), which themselves contain multiple discrete sites (e.g. Fonferek Glen State Park). Sites contain clusters of observations, whose spatial extent defines the

Figure 2. Screen grabs of the mobile interface visible to users, which exemplify the place-topic-site-observation hierarchy.

extent of the site. In this way, each successive layer in the hierarchy zooms the map extent to progressively narrower scales. When a user selects a specific observation, the mobile app replaces the map view with a full-screen view of the observation's content, including any user-defined textual comment associated with it. To add new content (Figure 3), a user navigates to the place, topic, and site of their choice, and selects the tear-drop icon at the bottom of the screen. The mobile app then prompts the user to define the geographic location of their observation, either by selecting the user's current geographic location or by dropping a pin at location of their choosing. The next screen allows the user to add a title, choose from among the defined media options — e.g. notes (i.e. textual comments), photo, video, or audio — and then actually record the observation using the iPhone's built-in capabilities. After adding a descriptive comment and selecting "submit," the observation is added to the map. The app is freely downloadable through Apple's App Store under the name WI Geotools Explorer. All content is stored and served up via www.arcgis.com, which serves as the back-end interface for adding new topic and sites layers, as well as moderating content.

Figure 3. Screen grabs demonstrating the process of adding observational content using the mobile app. From any given topic screen (A), users select the tear-drop-shaped "plus" (+) button in the lower-right corner, which brings up the Add Observation screen (B) on which the choose the media type and add a comment. Once and observation has been submitted, it appears on the topic map (C). When a user selects an observation's icon, its associated media is enlarged (D).

The web app (http://maps.aqua.wisc.edu/geotools/surfer/) is functionally similar to the mobile app, but was developed with to facilitate interactive content-browsing and place exploration, and to allow non-iOS users access to the geotools platform. The web app (Figure 4) contains a content scrollbar at the bottom of the screen and a permanent content-viewing pane to the left of the map, which allow for a more seamless and sequenced browsing experience. The web layout also promotes quicker navigation between topics and sites, and contain an additional layer of content filtering based on observations' media type. Like the mobile version, the web interface also allows users to upload original observations (with the exception of photos, whose sized caused excessive freezing and crashing).

Figure 4. An example of the web application interface, with drop-down menus for topics and sites (upper right), a scroll bar displaying each site's observations (bottom), and a viewing pane (left) to browse individual observations.

Content for both applications is routed and stored on ArcGIS.com, from which additional places, topics, and sites are initially defined (users can request the addition of a site through either app). This back-end interface also allows one to add various base maps and relevant spatial data layers (e.g. wetland delineations) to be defined for individual topics within the apps. This interface is also where content moderation occurs. In their current developmental phase, the geotools do not allow users to edit or delete observations; instead, both apps require users to flag individual observations, which alerts the research team to moderate it on the back end. Now that the research and development phase is complete, we are exploring ways to enable user-driven content moderation.

3.2 User-centered design process and application pretesting

Given this project's intention of being transdisciplinary, we followed a user-centered design (UCD) process to iteratively develop, pilot, and refine the web and mobile geotools platform. UCD is characterized as an iterative process that incorporates user feedback throughout the tool design process, roughly organized into the following steps: needs assessment; conceptual design; prototype development; formative assessment of the prototype; debugging and release; and a summative evaluation for informing future designs or application spinoffs (Norman, 2002). The underlying objective is to be responsive to users' experiences throughout the development process, since "by only asking for feedback after development is complete, user input can do little more than confirm or challenge decisions which would be too expensive to change" (Roth and Harrower, 2008: 63).

Several factors contributed to UCD step 1, including: conversations about creating a more community-driven geotools platform following the development and deployment of researcher-driven applications in the St. Louis River Estuary (e.g. Wagler et al., 2012); results from Robinson and Shepard's (2011) Great Lakes estuaries general needs assessment; and conversations with a FRV group comprised of individuals representing a variety of water-oriented interests and organizations across a variety of sectors (e.g.

business, monitoring/enforcement, research, and government). Through a nominal group process, these same participants also created and vetted a list of six topics and twenty sites that gave some structure to the Green Bay "place" in the geotools content hierarchy. Initial conceptual design (UCD step 2) was accomplished through the ESRI collaboration described above. Working prototypes (UCD step 3) for both the web and mobile apps emerged from both this collaboration and additional consulting work by University of Wisconsin-Madison's Division of Information Technology. A series of formative assessments and debugging efforts (UCD steps 4 and 5) began in May 2013. Members of the aforementioned FRV group were recruited to field-test a beta version of the mobile app, with participant feedback collected in the form of written comments and facilitated whole-group discussions. Nine additional field-testing workshops were convened between August and December 2013 with a variety of interest groups in the FRV, who were recruited based on recommendations from our initial contacts in the FRV. Participating groups included: students in middle school, high school, and college science classes; volunteers in a watershed monitoring program; members of hunting and fishing organizations; and conservation-oriented clubs affiliated with two regional colleges. Informal evaluations were conducted during and after these workshops, with user feedback elicited both in writing and in whole-group discussion among workshop attendees. Technical and conceptual changes (described in the Results section below) were incorporated pursuant to this feedback.

3.3 Participatory Geotools Piloting and Evaluation

Following the re-release of a revised version of the Geotools in March 2014, we piloted the apps with three community partners, including an area wildlife sanctuary (Partner 1), a conservation organization that maintains a large riparian parkway in the city of Green Bay (Partner 2), and a general ecology class at a local university (Partner 3), for a total of 40 users. In keeping with this project's participatory goal, we supported them in creating their own respective objectives for how the geotools would be put to use. Partner 1 elected to create a virtual guide to highlight some of the wildlife sanctuary's attractions. Partner

2 wanted to design a virtual ecotour, or pocket guide, that would educate visitors and everyday recreationists about the riparian parkway's ecological dynamics, access points, and ongoing management and restoration. The professor affiliated with Partner 3 charged her students with selecting a natural area or significant ecological site in the Green Bay area, visiting the site, and preparing an illustrated description of the site and its ecological significance. On our end, supporting our partners took the form of creating partner-specific topic layers and their associated sites in the geotools, providing initial geotools training to participants, and performing quick-response content moderation and technical assistance as needed.

Each partner was given six weeks after an initial participant training session to use the geotools in the field. Six iPhone 4 devices with limited data plans were loaned out to users who did not have their own device. Following each partner's piloting effort, we formally evaluated users' experiences (UCD step 6) with a written questionnaire. In total, 36 out of 40 users filled out the questionnaire, yielding a response rate of 90%. The questionnaire, which included Likert-type items and open-ended questions, was designed to elicit multiple aspects of users' experience with respect to the geotools specifically, as well as their general perceptions of the use of mobile apps and electronics in pedagogical and natural settings (Table 1).

3.4 Analysis of user-contributed content

In addition to analyzing questionnaire responses, we qualitatively and spatially analyzed the content of the observations themselves. Though full results from these analyses are reported in a separate paper, this paper includes some exploratory, descriptive results in order to demonstrate the kinds of analyses that the geotools enable. Qualitative content analysis included open coding of all note observations and textual comments appended to any other observation type (Slater, 1998), as well as visual analysis of all photo and video observations (Rose, 2012). These analyses were undertaken in order to identify possible patterns within the overall body of observations contributed by our users (Lutz and Collins, 1993). All photos and videos were visually analyzed and categorized according to each observation's compositional distance or scale, as well as its primary compositional content. Two distance codes were applied according to whether the observation featured a close-up (hereafter referred to as mesoscale) composition, or a broader landscape (hereafter referred to as macro-scale) composition.

Spatial analysis was conducted in ArcMap Desktop 10.1, and consisted of exploring the proximity of user-contributed observations to various classes of water bodies (e.g. lakes, rivers, wetlands). We were interested in conducting this analysis because proximity to water, and water's associated sensory and recreational qualities, emerged as a key theme for participants in a related study (Eanes et al., 2016b) in order to explain their sense of place in northeastern Wisconsin's coastal communities. Accordingly, we used the "Near" tool in ArcMap to measure the distance in meters between each observation and its most proximate surface water feature within the WI DNR 24k Hydrography feature class. Two-sample 1-tailed t-tests were conducted between each of the water feature classes in order to test the null hypothesis that there was no significant difference in observations' mean distance to water among the five most prevalent water classifications in our study area (i.e. lake/pond, river, perennial stream, intermittent stream, wetland).

4. RESULTS

4.1 UCD feedback and interface design changes

Overall use of both the mobile and web apps was much lower than we expected. Despite training over 150 individuals throughout the pretesting/prototyping phase of the project, only 99 observations of any type were recorded, compared to 772 observations recorded by 40 participants during the a subsequent piloting phase. We attribute this low use to technical and methodological causes, which we elaborate on more fully in both the following section and in the discussion section.

Several technical and methodological issues related to the geotools were identified during the application pretesting steps of the UCD process, resulting in changes to both the geotools interface and our subsequent piloting approach. Technical challenges included data connectivity issues due to uncapped file sizes for photo, video, and audio observations. Particularly in remote geographic areas with compromised cell signal strength, these large file sizes lead to mobile app crashes and delays, resulting in user confusion and frustration. To address this we limited the file size of uploaded content, and restricted the ability of users to upload photos via the web application, which easily got bogged down with high-resolution photos. Together, these decreased the crash rate substantially. In addition to somewhat frequent crashing, users commented on the process of adding an observation, which required them to sequentially choose a place, topic, and site before they were able to even initiate the process of actually recording content. Users would often navigate to the wrong topic or site, only to have the subject of their observation change positions or move before they could capture it with the geotools. As a result, we stripped away as many steps as we could to simplify the observation-adding process. Instead of having the mobile app open to a generic homepage, we modified the mobile app to use the phone's location-based services to display a map corresponding to the place, topic and site closest to the user's present geographic location. At the same time, we created a permanent scroll bar at the top or any given screen, allowing users to quickly jump from topic to topic without having to navigate in and out of the app's content hierarchy (see Figures 2 and 3). In effect, these two design changes exposed the user by default to the most place-relevant content at any given time, while allowing them the ability to easily explore more remote content without having to make multiple, discrete navigational decisions. Finally, we added a dedicated settings menu, built-in help documentation to pre-empt user struggles, and a feature allowing users to request the addition of a new site. Collectively, these latter modifications were undertaken to remove barriers of communication between users and the research team.

4.2 Evaluation of user experiences during piloting phase

Overall, piloting participants reported that the mobile and web geotools were somewhat easy to use (Table 2), with a large majority (78%) saying that the mobile app effectively or very effectively engaged and/or interested them in their surrounding landscapes. A significantly greater share (39%) of respondents said that, relative to an average outdoor experience, they were more likely or much more likely to notice plants, animals, or other natural features while using the mobile app, compared to 5% who said they were less likely than usual to notice these landscape elements. Respondents indicated that the geotools fairly enabled them to upload content that captured the local features most important to them. About 40% indicated that they would continue using the geotools after the research phase of the project officially ended. Almost half (47%), however, experienced one or two technical issues while using the geotools, while 42% experienced either several technical issues or several *significant* technical issues.

Table 1. Quantitative variable and open-ended items (O1-5) from the geotools evaluation questionnaire

Variable	Item	Scale
Ease_use	Please tell us how easy it was for you to use the Green Bay geotools mobile application.	1 (very difficult) ..…… 4 (very easy)
Engage	Based upon your initial use, please rate how effectively the app engaged or interested you in your landscape's surroundings.	1 (very ineffectively) … 4 (very effectively)
App_ability	Please rate the ability of the app to allow you to submit photos, text, audio, or videos that capture the landscape features most important to you.	1 (very poor) ……….. 5 (excellent)
Future_use	How likely would you be to use this application outside of the context of this project?	1 (not at all likely) …… 5 (very likely)
Tech_issues	Did you experience any technical issues while using the app?	1 (none) ……………..4 (several significant issues)
Reception	Please rate how often the quality of your *cell reception* interfered with successfully using this application.	1 (never) …………….. 5 (almost always)
Notice	Compared to an average experience outdoors (for you), how much more (or less) likely were you to notice plants, animals, or other natural features of interest/concern when using the app?	1 (much less likely) …… 5 (much more likely)
Accessibility	Please rate your level of agreement with the following statement: In general, when I spend non-work time outdoors, I like to be accessible on my cell phone.	1 (strongly disagree) ….. 5 (strongly agree)
Nature_apps	Please rate the frequency with which you perform the following activity: I use smartphone apps or other mobile technology to help me interpret/identify/appreciate plants, birds, landscapes, or other natural features in my bioregion.	1 (never) ……………… 5 (very frequently)
Tech_prefer	Please rate your level of agreement with the following statement: I prefer to observe/interact with landscapes with as little technology around/with me as possible.	1 (strongly disagree) …... 5 (strongly agree)
O1	What was your favorite characteristic/feature of the app itself (either mobile or web)?	
O2	What was your favorite part (or anecdote) from the experience of *using* the app (either mobile or web)?	
O3	What was your least favorite characteristic/feature of the app itself (either mobile or web)?	
O4	What was your least favorite part (or anecdote) from the experience of *using* the app (either mobile or web)?	
O5	What suggestions do you have for improving the app?	

Table 2. Bivariate correlations among questionnaire items using Pearson's *r*, mean, mode, and standard deviation (N = 36). *p < 0.05 (2-tailed) ** p < 0.01 (2-tailed)

Variable	Ease _use	Engage	App_ ability	Future _use	Tech_ issues	Reception	Notice	Access- ibility	Nature _apps	Tech_ prefer
Ease_use	1	0.20	.65**	.41*	-0.58	0.09	0.04	0.02	0.1	0.04
Engage		1	.39*	.52**	-0.25	-.34*	0.17	0.12	.35*	-0.06
App_ability			1	.43**	-.66**	0.06	-0.04	0.03	0.00	0.03
Future_use				1	-.33*	0.11	0.12	0.04	.47**	-.36*
Tech_issues					1	0.12	-0.12	-0.09	-0.07	0.06
Reception						1	-0.03	0.00	0.18	-0.01
Notice							1	0.06	0.02	-0.11
Accessibility								1	0.15	-0.32*
Nature_apps									1	-.41*
Tech_prefer										1
Mean	2.2	2.9	2.9	3.0	2.5	1.7	3.3	3.4	2.3	3.6
Mode	2	3	4	3	2	1	3	3	1	4
Std. Dev.	0.8	0.7	1.0	1.2	0.9	0.9	0.7	1.0	1.2	0.8
N	36	36	36	36	36	34	36	36	36	36

Qualitative analysis of the open-ended responses associated with each questionnaire item revealed that crashing was the most frequently cited technical issue (Table 3). Based upon application analytics and the timing of users who contacted us with technical issues, the majority of crashing episodes occurred on mobile devices that were running the original (not the updated) version of the mobile app, which was demonstratively more prone to crashing (this phenomenon likely occurred due to the fact that users affiliated with Partner 3 were introduced to the geotools one week before the new mobile version became available, and despite our best efforts to contact users, not all users updated to the latest version). Therefore, we speculate that the number of users reporting more than one or two technical issues would

Table 3. Most frequently cited technical issues associated with the mobile app

Code	Frequency
crashing	41
difficulty uploading observations	40
general technical bugs (e.g. freezing, text not uploading)	16
difficulty downloading others' observations	13
slow app responsiveness (e.g. when uploading content)	7

likely decrease significantly in the event of re-evaluating users' experiences at a later date. When asked about how often the quality of cellular reception interfered with the mobile app's functionality, most users (82%) reported that service connectivity was rarely, if ever, an issue. Interestingly, the users who borrowed our six mobile devices tended to report relatively more frequent connectivity issues, probably due to the fact that the our devices' cellular carrier (as prescribed by our university) differed from the most popular carriers in northeast Wisconsin, and almost always had less reliable coverage.

Based on a combination of bivariate correlations between questionnaire items using Pearson's *r*, as well as individual participant's open-ended responses, we can make several inferences about users' experiences (Table 2). First, the geotools' perceived ease of use exhibited a moderate-to-strong positive correlation (.65, $p < .01$) with users' assessment of the apps' ability to upload content that captured the local natural features of greatest interest, and a weak-to-moderate positive correlation (.41, $p < .05$) with users' intention to use the geotools outside of the research project. Participants' likelihood of using the geotools beyond the extent of the research project was also moderately positively correlated with the degree to which geotools interested and/or engaged users in their surrounding landscapes (.52, $p < .01$) and functional ability to support users' attempts to upload content of interest (.43, $p < .01$). Moreover, the number of user-reported technical issues was negatively correlated, respectively, with users' perception of the apps' ease of use (-.58, $p < .01$), ability to upload local content of interest to the user (-.66, $p < .01$), and users' intention to continue using the app outside of the research project (-.33, $p < .05$). In addition to crashing, users cited issues with uploading and downloading observations, slow app responsiveness, and other general technical bugs as barriers that impeded their user experience. Users frequently labeled these technical challenges as "frustrating" and "confusing," and were overwhelmingly more likely to rate the apps' usability and attractiveness lower than users who had less challenging experiences. Despite these reported challenges, users' overall attitudes towards the geotools and their design were largely positive.

Overall, our users provided us with a substantial amount of feedback regarding the geotools' features, capabilities, and impact, based on their answers to our questionnaire's open-ended questions (Table 4). Participants were most enthusiastic about being able to mutually share and view content with other users. Users described how this crowdsourced sharing helped them encounter and visualize places that they may not have previously visited. Many wrote about how interacting with the geotools changed the way they viewed landscapes, saying things like "It made me look at my surroundings more closely," or "Instead of just walking through, the app had me stop and appreciate what was around me." Several specifically noted things they had learned about their surrounding ecosystems while using the mobile app. And some even mentioned that these virtual encounters provided them with an incentive to go and explore a new place. Other features that users liked included the app's capability for real-time uploading of their contributed content into the map, which was immediately visible to both them and others. Others appreciated having the mobile app as a sort of pocket guide that provided relevant, place-based information about their surrounding landscape. One user, for example, noted how "Having never been to this area of the park before, it was helpful to see the trail maps and see that I was on the trail."

Even users who expressed an intention to keep using the geotools outside of the research project, however, made some helpful criticisms. Thirteen users wrote about their frustration with the geotools' built-in character limit for textual comments appended to photo or video observations. These users wanted more flexibility to describe and interpret their observations. Others expressed a similar annoyance at no longer being able to upload photos via the web application, and at not having the ability to edit or delete their own content. (These two measures were intentionally undertaken, respectively, as a corrective

Table 4. Participants' appraisal of the geotools' capabilities and associated user experiences, as qualitatively derived from open-ended questionnaire items

Category	Code	Frequency
Favorite geotools features	ability to view others' uploaded content	15
	ability to upload and share content with others	13
	easy/intuitive navigation	8
	easy, real-time uploading	7
	interactive map	6
	availability of place-based information	3
Least favorite geotools features	Character cap associated with photo captions	13
	inability to upload photos via web app	8
	confusing interface	7
	inability to edit own content	6
	too many steps involved in uploading content	4
	inability to upload multiple observations simultaneously	2
Positive user experience or impact	prompted more mindful exploration of landscapes	23
	paid closer attention to landscapes	16
	enjoyed viewing others' content	11
	app provided incentive to explore new places	10
	reaffirmed love of outdoors	8
	learned something new about surrounding landscapes	8
Neutral user experience or impact	user already pays close attention to landscapes (i.e. no need for app)	10
Negative user experience or impact	technical issues clouded app experience	25
	confused by interface	10
	wished there were Android version	3

measure to improve the geotools' speed and decrease the frequency of crashing episodes, and as a safeguard against content being accidentally or nefariously being removed during the research phase of the project). Smaller numbers of users — particularly those who did not own their own smartphone and were inexperienced with mobile apps — noted that they found the mobile interface to be confusing, and that the geotools involved too many discrete steps to upload content. And as has been reported earlier, numerous participants mentioned that the mobile app crashed and had to be reopened; as an isolated event, crashing was not a critical issue (according to users), but when it happened repeatedly or in quick succession, it became understandably burdensome on the overall user experience. Three users, for example, said that they were sufficiently intrigued by the capabilities of the mobile app to keep using it beyond the life of the project, as long as the technical bugs were fixed.

Given the rapidly advancing accessibility of technology in even remote places, we were also interested in understanding users' general attitudes towards the use of mobile phones in natural landscape settings. Respondents were generally split on the frequency with which they use mobile apps to identify or interpret elements of their bioregional landscapes, with 56% rarely or never using such technology, and 44% using mobile apps sometimes or often. A plurality of respondents (45%) expressed that they liked to be available on their cell phone when spending non-work time outdoors, while a much smaller share (17%) prefer to be disconnected. Participants who prefer connectivity described how much they love taking pictures of nature and landscapes; one user, for example, wrote emphatically that "nature is supposed to be enjoyed with a camera," and that the presence of a camera or phone does not preclude a close experience with natural settings. Others mention how they "like keeping in touch" while in the outdoors, and how their phone "gives a sense of security," particularly in cases of emergency. 39% registered a neutral opinion on the matter. Interestingly, a majority (58%) of respondents said that they prefer to interact with landscapes with as little technology around as possible, while 36% expressed a neutral opinion. Overall these variables (Accessibility and Tech_prefer) exhibited a weak negative correlation ($-.32$, $p<.05$). Altogether, the surprisingly large share of participants expressing neutral opinions could simply be a product of the relative newness of nature-oriented apps (several respondents expressed that they did not own or were relatively new owners of a smartphone) and therefore a function of people not yet having made up their mind. Notwithstanding our admittedly small sample, this neutrality reflects the environmental education community's own ambivalence towards technology in nature (Greenwood and Hougham, 2015).

4.3 User-generated content

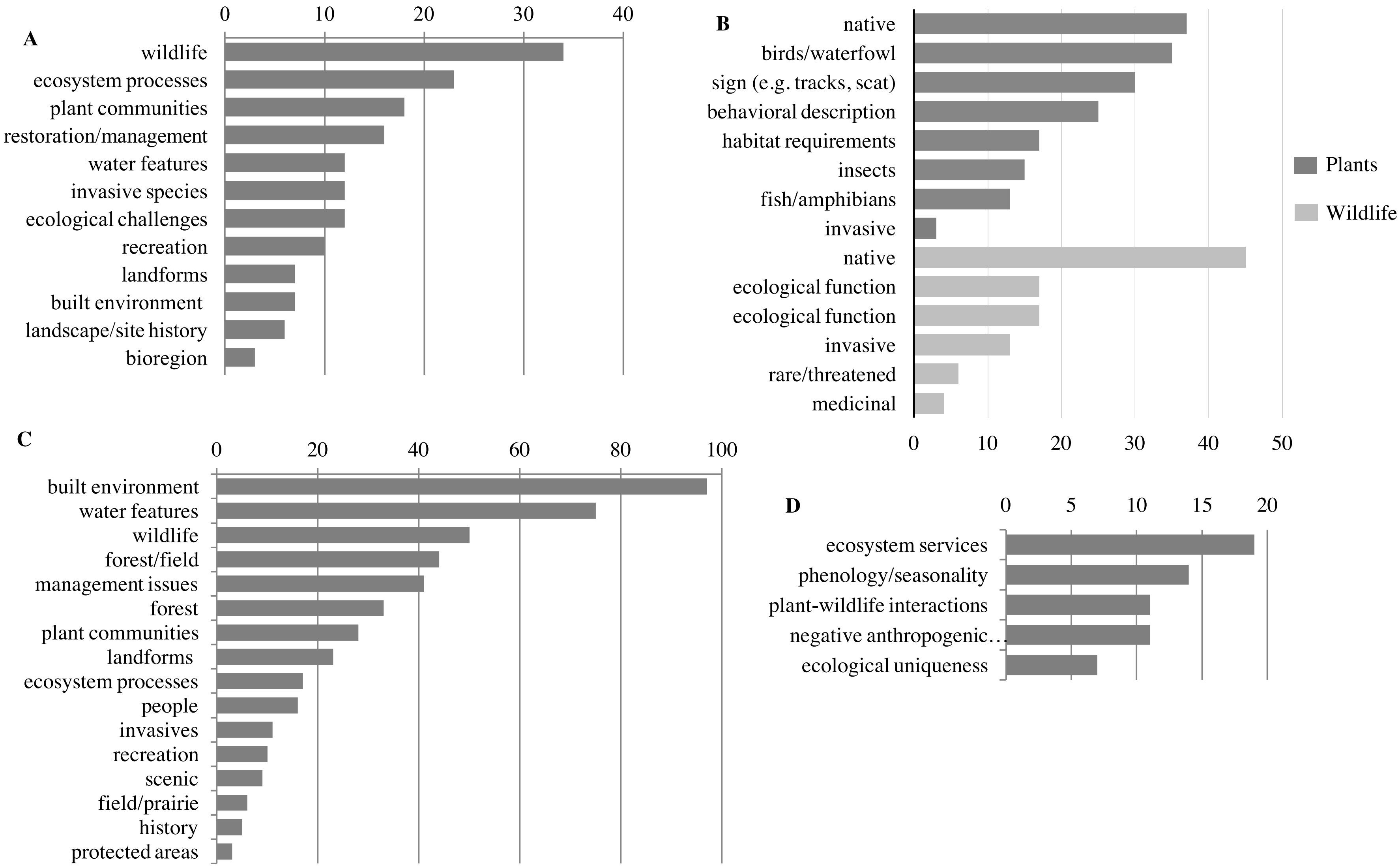
By the end of their respective 6-week sessions, all three community partners had contributed content in line with their initial objectives. In total, our 40 participating users generated 772 observations, dominated by photos (81%), notes (17%), videos (2%) and no audio. Partner 1's virtual tour of their wildlife sanctuary consisted of 50 observations — all photos. Partner 2, who set out to design a virtual ecotour for the riparian parkway they manage, included discrete topic layers denoting access points, vistas, and areas of ecological interest. In total, Partner 2 uploaded 150 observations — also all photos. Students affiliated with Partner 3 illustrated the ecological significance of natural areas of interest, recording 569 observations that consisted predominantly of photos (75%) and notes (22%), and a few videos (3%).

Considered collectively, the observations reveal broad trends in the landscape-based subjects that caught users' attention (Figure 5). Note observations (Figure 5A) most frequently included descriptions of typical wildlife; ecosystem processes and characteristics; plant communities typical of a particular site; and restoration and/or management initiatives. Notes also (though less frequently) described sites' water features, invasive species, and general ecological issues or challenges. Photographic observations, which constituted the vast majority of observations across all partners, featured a much narrower breadth of subjects when taken at close ranges (mesoscale) relative to those that took more of a landscape (macro-scale) perspective. With the exception of three photos that featured various fungi, mesoscale photos (Figure 5B) exclusively depicted plants, wildlife, or their associated characteristics. Among photos featuring plants, native species were most commonly depicted, and appear at more than three times the rate of invasive plants. Other plant-related mesoscale photos depicted individual plants' ecological function and habitat requirements, along with descriptions of native plants that are medicinal, rare, and/or threatened. Mesoscale photos primarily featuring wildlife followed a similar pattern, depicting native species most often, and twelve times more frequently than invasive species. The classes of wildlife most frequently represented included birds — especially waterfowl — followed by insects and fish, and amphibians. Also featured were animal sign (e.g. tracks, scat, woodpecker holes), behavioral descriptions, and habitat requirements.

For their part, macro-scale photos featured a comparatively broader variety of primary subjects. Interestingly, photos most frequently depicted elements associated with built environments and designed landscapes, such as trails, boardwalks, signage, pavement, and other supporting infrastructure. The next-most-frequent subjects depicted water features, such as lakes, rivers, ponds, streams, or wetlands; various wildlife-related subjects, including birds/waterfowl, habitat, and megafauna; forest-to-field landscapes; landscapes management issues and activities; forested landscapes; unique plant communities; and specific landforms, such as bluffs, escarpments, or caves. Interestingly, people only appear in 16 photos, and when they do are shown either in recreational or landscape-management capacities; this likely is a direct result of our institutional review board's requirement that we dissuade users from depicting peoples' faces (for matters of privacy), rather than indicative of user preferences. Finally, a relatively small share of photos (9%) included comparatively longer interpretive captions that described related but secondary subjects. Among these, 19 described ecosystem services, and 14 referred to landscape phenology or seasonality (e.g. bird migrations). Eleven described plant-wildlife interactions, eleven others highlighted negative anthropogenic effects (e.g. erosion, pollution), and seven addressed the landscape's perceived ecological uniqueness.

In addition to investigating the subjects of user-generated content, we were also interested in exploring the spatial patters of observations. Since results from a related study (Eanes et al., 2018) with some of this project's participants revealed that proximity to certain landscape characteristics – particularly water – was important components of participants' sense of place, we analyzed the spatial proximity of all observations to nearby bodies of water. Results from the spatial analysis are summarized in Figure 6 and

Figure 5. Frequency of primar subjects of note observations (A), mesoscale photos (B), and macro-scale photos (C). Figure (D) depicts the frequency of secondary subjects of photos based upon user-contributed comments appended to observations.



spatially visualized in Figure 7. Overall, the median distance between an observation and a water feature was 125m (mean = 259m). Observations were most frequently located near intermittent streams (n = 246), followed respectively by lakes/ponds (n = 196), perennial stream (n = 191), wetlands (n = 130) and rivers (n = 83). Among the five classes of water features, the mean distance between observations and the nearest water body was smallest for rivers (mean = 134m), followed respectively by perennial stream (mean = 207m), intermittent streams (mean = 246m), wetlands (mean = 298m) and lakes/ponds (mean = 403m).

Figure 6. Distribution of observations according to the distance between an observation and its closest water feature.

Figure 7. Maps depicting a selection of observations in the GB area, the inset close-ups of observations and their nearest water features (Bowers Creek and Mahon Woods Creek, respectively)

To further evaluate spatial patterns of the observations, we ran a basic spatial statistical analysis with ArcMap 10.4. Specifically, we examined spatial clustering of observations at two scales using the Average Nearest Neighbor tool, which compares the observed mean distance between points to the expected mean distance if points were distributed randomly within the selected area. It calculates a z-score and significance of whether observations are more clustered or dispersed than expected by chance alone. First, we ran the tool for a single topic across multiple sites: Green Bay-UWGB Ecology class, since we would expect observations to be clustered by site, and it would not make sense to consider distribution across topics. The observations for this topic showed significant clustering ($z=-43.77$, $p<.001$). We then looked at distribution of observations within a single site (Peninsula State Park) of the same topic. In this case, observations were more dispersed that expected by random chance, though this effect was only marginally significant ($z=1.91$, $p=.056$). These analyses were not intended to produce a representative comparison or test of spatial distribution of observations within our study; rather, they constitute a proof-of-concept pilot to illustrate how observations generated from the geotools might be used to quantitatively evaluate specific environmental patterns in future applications.

5. DISCUSSION

Roth and Harrower (2008: 47) have characterized the UCD process of developing and deploying interactive tools as akin to "trying to build the plane while it's flying" — an observation that accurately reflects our own experiences. Figuring out how to motivate use of tools that were constantly evolving, and the need to satisfy the goals of both our community partners and our own research, proved to be a complicated and fascinating task. Based on the results of both pretesting and piloting the geotools, we discuss here challenges and limitations of our approach, and propose potential solutions that could guide future iterations of the geotools and/or related efforts.

5.1 Technical and design considerations

As resources and time permit, for example, we envision three modifications to the geotools platform. First, we plan to create an "offline" mode for the mobile app, which would permit users to upload a variety of observations under conditions of low cell signal strength. Poor cell coverage and signal strength readily occur in more remote areas, some of which coincide with the very places of interest in this research. All observations made by a user in the offline mode would be added to the interactive map once the user regained a more reliable signal. The benefits to an offline capability include the ability of users to visit and document broader geographic extents, regardless of cell coverage. Large media such as videos or high resolution photos, moreover, could be more readily accommodated in this mode. The associated tradeoff, however, is that users would not have the same experience of seeing their contributed content added to the map in real time — an experience that users repeatedly said that they enjoyed.

Second, in order to accommodate user editability, we may consider requiring participants to create an anonymous password-protected user account before contributing observations. This would allow users to edit or remove their own content without having to go through the research team, while simultaneously providing a modicum of accountability; users, for example, could be limited to editing their own content, leaving others' observations off-limits. While this extra step of creating an account may deter some users, such screening-and-security features have become commonplace in the marketplace of online and web apps. From a research standpoint, linking user accounts to the individual users' observations could enable deeper and more robust observational content analyses; as the geotools are presently designed, it is impossible to trace any given observation (or set of observations) to a specific user, which diminishes the breadth of possible analytical capabilities regarding user behavior. User accounts, while commonplace in countless applications, nevertheless constitute a potential pathway for participant anonymity and confidentiality to breached, something that will at the very least need to be acknowledged to both participants and institutional review boards.

Third, we plan to broaden the limits currently placed on notes and photo observations in both geotools. Doing this would allow participants to add more of their own interpretations of the observations they make, allowing their voices and perspectives to be documented more authentically. Given the challenges cited above, though, removing these limits will most likely only be feasible if an offline mode is concomitantly developed. Absent this, longer captions and larger photo sizes will continue to cripple the geotools in geographic areas limited by cell service, and lead to predictable user frustration.

Despite these proposed improvements, legitimate questions remain about data storage and ownership, as well as how to provide ongoing technical support to current and future community partners. At present, for example, minor back-end preparation is required to add or modify names in the geotools' existing place-topics-sites hierarchy. While the level of expertise required to make these changes is not prohibitively high, we have not yet devised a way to completely open up our platform to user amendment. This challenge of continuing to support ongoing use and maintenance of a platform like ours, while not unique to this project, is a significant consideration that similar participatory and/or UCD initiatives must address (and not just at the end of the development and pretesting phase). The project partners at Wisconsin Sea Grant, UW-Madison, and UW-Extension are working on the institutional supports needed for long-term ownership and moderation. This work includes conversations with local partners that have interest in the application, as well longer-term opportunities through the partnering institutions.

Overall, though, our users consistently told us — both informally in workshop settings and formally in their evaluations — that they were intrigued by the geotools concept, and generally enjoyed the experience of using them. Importantly, their perceptions of the apps' functionality and general usefulness was positively associated with the number of technical issues encountered in the field, rather than anything inherent to the apps' design or purpose. Put another way, the technical issues described herein have potential design solutions, which would in all likelihood improve user perceptions and experiences. This position, moreover, is certainly preferable to its hypothetical inverse, in which we would deploy a flawlessly functioning platform that participants found prohibitively difficult to use, or worse, had no interest in using.

5.2 Qualitative and spatial content analysis

Overall, the content and spatial location of the data generated by our users illuminate interesting trends vis-à-vis what sorts of landscapes (and landscape characteristics) are of greatest interest to our participants. The built environment was quite salient throughout all categories of observations, reinforcing the ubiquity and closeness of designed landscapes for our participants; examples of these include depictions of resorted or managed areas in and around the city of Green Bay, as well as recreational paths, trails, and other supporting infrastructure. Water bodies of all types also featured prominently in all observation types; perennial and intermittent streams in particular were the most abundant and occurred in closes spatial proximity (on average) to observations. However, the strong user bias towards photographs (as opposed to textual or other observations) and the multi-contributor nature of the platform largely precluded the emergence of recognizable spatial narratives – at least any resembling those created in other, researcher-driven contexts (e.g. Silbernagel et al., 2015; Wagler et al., 2012). While this acknowledgment does not preclude the possibility of future narratives emerging organically – e.g. around a particular issue in the particular place – our experience suggests that the generation of narratives may require more organization and user intention, and this will be an emphasis of our future work. Admittedly, we hesitate to infer too much from these cursory qualitative and spatial analysis, given the varying prompts that guided our three community partners, and the fact that this research was primarily motivated by the geotools' design and deployment, and our evaluation of users' experience. Despite these limitations, the foregoing analyses point to the intriguing analytical capabilities of the geotools. The geotools' combination of location awareness and multimedia content, we argue, could provide all manner of rich data sets for both researchers and practitioners, and offer analytical opportunities limited only the scope of the motivating questions or prompt, and the degree to which any outcome is perceived as relevant and valuable to the users themselves.

5.3 Methodological challenges and considerations

Aside from technological hurdles, user motivation was an integral component of this project and an ongoing challenge. During the iterative pretesting phase, we were continually perplexed by the apparent disconnect between the initial enthusiasm expressed by participants at training workshops, and the relatively low levels of use once participants left the workshop to test the geotools on their own.

Technical issues (e.g. crashing, freezing) certainly explain part of this usage gap, along with the fact that a lower-than-expected share of users had access to an iPhone. But usage remained relatively low even after six iPhones were temporarily loaned out to users near the end of the pretesting phase. As we prepared for the more formal piloting phase, we noticed that relatively higher levels of engagement (in terms of the amount of user-contributed content) occurred in training workshop formats that contained a structured, limited timeframe (approximately 1-2 hours) for users to go and use the geotools and then report back to the research team. This approach, while successful in generating enough feedback for us to iterate a more refined version of the geotools, nevertheless felt overly scripted and somewhat confining. Participants were limited both geographically and temporally, and therefore highly constrained in the breadth of landscapes they could interact with and, ultimately, in the content they could contribute. Our alternative pretesting workshop approach, however, in which users were given two weeks to freely test the geotools before reporting back, yielded too little user engagement to be appreciably useful to our UCD process.

Accordingly, as we moved into the piloting phase of the project, we modified the latter approach in an attempt to preserve the freedom of unstructured, unscripted geotools use. The core of this modification involved abandoning the six catch-all topics that early geotools users had collectively created, and which had provided thematic structure to guide subsequent user observations. Though initially conceived as a means for enabling a multitude of users to construct multilayered deep maps and spatial narratives for the FRV's landscapes, we opted for an approach that prioritized narrower, community-partner-driven topics and sites. Within this latter approach, each community partner created their own respective topics and sites based on their needs and objectives. This targeted engagement made the experience of using the geotools and exploring the resulting content much more personalized and therefore relevant for any given user. Having a stake not only in the interface UCD process, but also in the process of framing use-oriented questions and prompts, was critical for increasing the level of user interest and engagement. Ultimately, this flexibility and adaptive user engagement proved successful at eliciting significantly higher geotools use, while simultaneously supporting the ability for users to freely experience the geotools at times and settings of their choosing. In this sense, we unwittingly extended the UCD approach, expanding its core principles to include the consideration of user-centered *use*.

Admittedly, this narrower focus was not how we envisioned the project at its outset. Consequently, our own research objectives had to be periodically negotiated and reconciled with those of our community partners — a dynamic tension that in fact is quite common in community-based participatory research. For example, our objective to quantitatively evaluate the applications' capabilities to promote spatial literacy and user engagement was complicated by the lack of initial unstructured, in-the-field application usage, and displaced by the time required to redesign both the application and our approach to engagement. But we argue that the depth of participation and geotools usage that we gained with this tailored approach more than made up for what we gave up in breadth. Moreover, these challenges of user engagement are consistent with empirical investigations of citizen science participants, which has observed relatively high program drop-out rates, uneven and disproportionately low contributions from a majority of participants, and the need for citizen science initiatives to maximize the real and perceived benefits of participation (e.g. Nov et al., 2011; Eveleigh et al., 2014; Rotman et al., 2012).

At the same time, technologies and applications – even those whose explicit intention is to foster greater user engagement with nature and landscapes – have been questioned by both theorists and practitioners (e.g. environmental educators) alike for mediating and distracting from actual experiences with nature, and their tendency to cheapen or commoditize those experiences that do occur (e.g. Kahn, 2011; Baudrillard, 1994; Chambers, 2007; Igoe, 2010). Likewise, nature-related and citizen science apps are themselves just one among countless apps vying for individuals' limited bandwidth within the larger social media and Web 2.0 ecosystem (Castells, 2011; Arts et al., 2015; Maffey et al., 2015).
While some of the disparities between anticipated and observed rates of use may be due to these so-called digital distraction and oversaturation effects, our formal and informal evaluation of users' experiences

suggests that the technological shortcomings of the app and the degree to which it enabled users' predefined goals had the most immediate effect on user engagement and persistence.

6. CONCLUSIONS

While this project's relatively small sample size (n = 40) limits our ability to validly make broad or generalizable claims about people's landscape preferences, values, or experiences, our data support two conclusions related to our original research objectives. Respectively, these conclusions point to (1) the geotools' technical capabilities, transdisciplinary versatility, and potential application in transdisciplinary and/or participatory projects; and (2) the sorts of landscape-related experiences the geotools can facilitate.

First, the geotools have the capacity to support transdisciplinary information-sharing and data analysis — a capability that will only be enhanced with the additional development and modifications outlined above. Users from a variety of backgrounds and affiliations successfully interacted with the geotools, contributing content through both platforms. And while the data that each community partner produced reflected their own respective goals as opposed to researcher-derived prompts and questions, the subjective breadth and spatial attributes of the content they generated underscore the geotools' versatility and potential future uses in participatory settings. For example, we foresee opportunities for the geotools to support various modes of public participation in scientific research efforts, including landscape-oriented citizen science and/or volunteer monitoring. If appropriately set up on the back-end, the geotools could potentially improve data-gathering efficiency and accuracy, or provide qualitative context regarding on-the-ground conditions (e.g. photos of water quality or aquatic invasive) to complement traditional measurements (e.g. Secchi disk readings). In addition, the geotools could enhance the spatial accuracy of visitor- or resident-employed photography, offering an additional layer of analytical potential to these research traditions that shed light on people-landscape perspectives and sense of place. Relatedly, the geotools could add more texture and narrative elements to (cultural) ecosystem services mapping and assessments, thereby bolstering participants' voices and perspectives.

Second, the geotools have the ability to engage users in experiencing and/or learning about their surrounding landscapes. This, of course, varied considerably from individual to individual, based not only on the technical challenges that users encountered, but also on their differing preferences for cellular accessibility and technological mediation of experiencing landscapes. Whether or not these attitudes towards the technology-nature intersection persist and/or evolve remains a viable question, and doubtlessly will color the sorts of experiences that users have with our geotools. And though it was beyond the scope of this research to test the learning outcomes of people who encountered or interacted with the content created by our community partners, the evaluative feedback we have received so far certainly merits further inquiry. For example, what do people learn and how do they experience landscapes differently when guided by a virtual ecotour/interactive map compared to traditional signage or place markers? What sorts of observations do people capture in relation to specific landscape-oriented questions? Relatedly, how do mobile-mediated landscape experiences influence where people go for leisure, tourism, and recreation? And can mobile and web-based platforms like ours impact the spatial dynamics of people's landscape encounters and explorations, or simply reify patterns of where people feel most comfortable, safe, or a sense of belonging?

Future deployments of the geotools will be required to answer these and related questions. Gathering enough quality data to sufficiently answer these questions, though, will require relatively high thresholds of user engagement. Based on our experience in this project as well as the literature on participatory and transdisciplinary research, the most fruitful engagements will occur in settings and partnerships that offer mutually beneficial and relevant learning opportunities both for users and researchers. Creating such relationships requires considerable knowledge of partners' values, needs, and priorities — especially on the front-end of research projects, but also throughout all stages of project implementation. As our partners' values and priorities evolved and/or became better understood, attentiveness and adaptation were critical for fostering engagement with the geotools and the landscape-related content generated throughout the project. Framing research questions and related prompts/tasks, in terms that aligned with partners' needs and desires, was essential for making our project relevant to all parties involved — an outcome that has implications for any participatory and/or transdisciplinary endeavor that seeks to meaningfully engaging the public in landscape research and practice.

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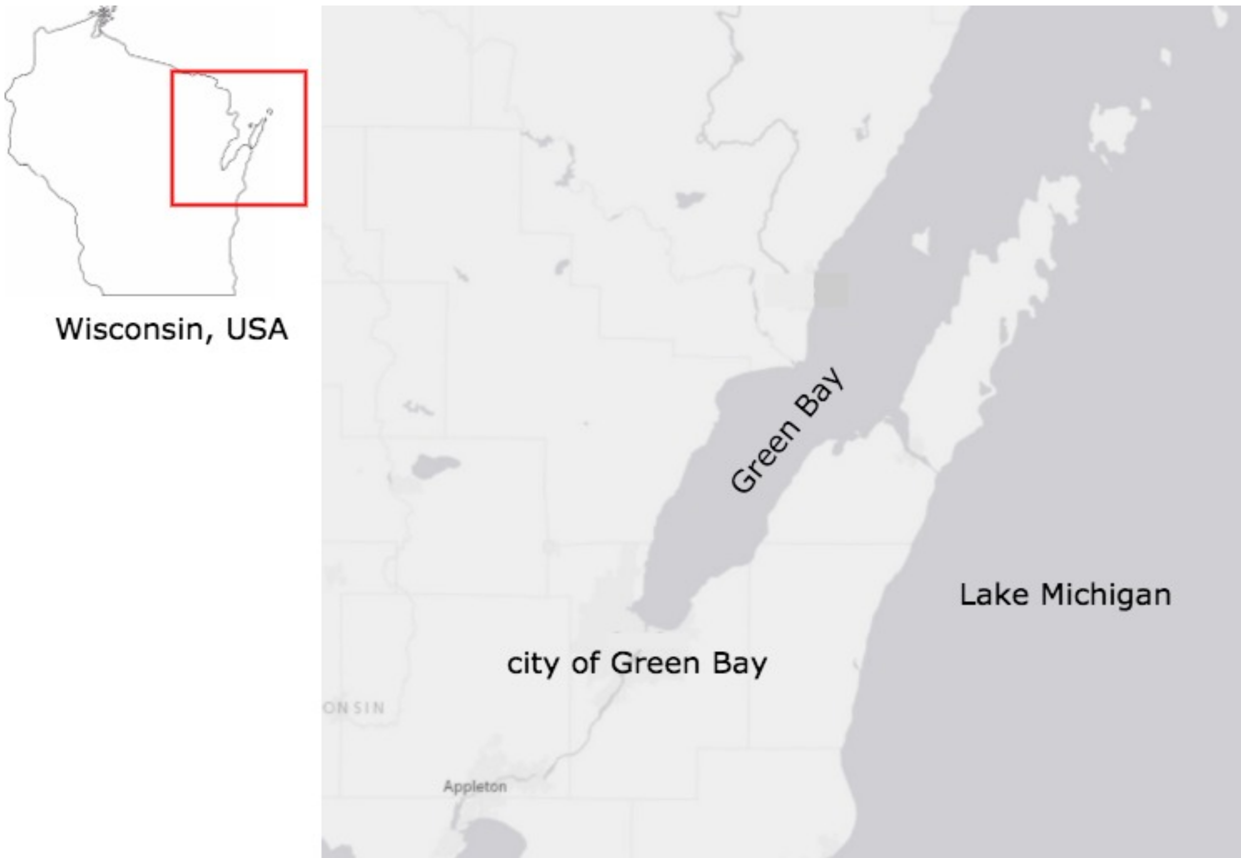


Figure 1. Study area of northeast Wisconsin and its constituent bioregions. Map adapted from US EPA.

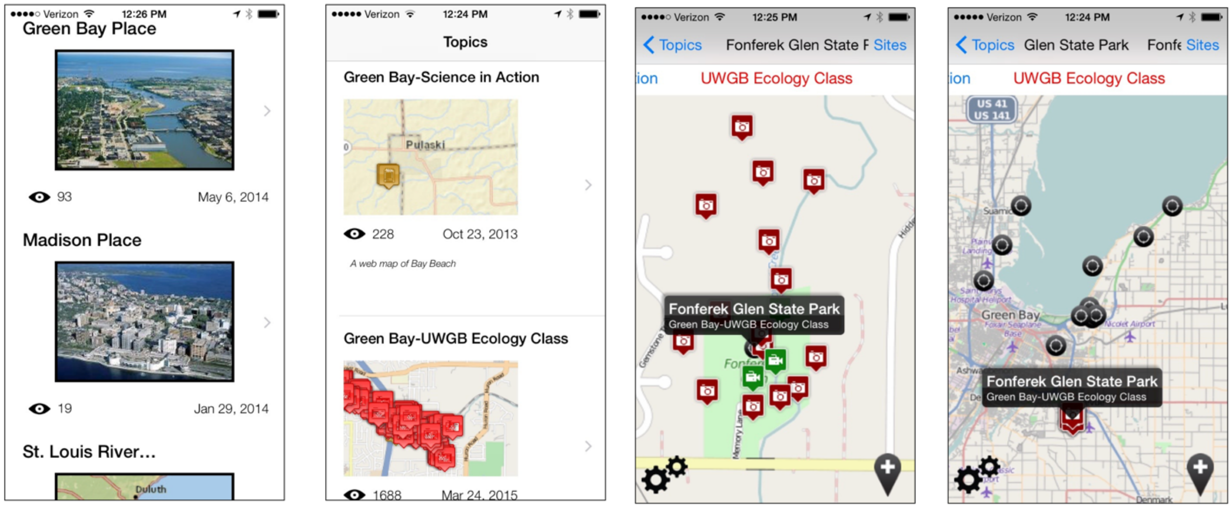
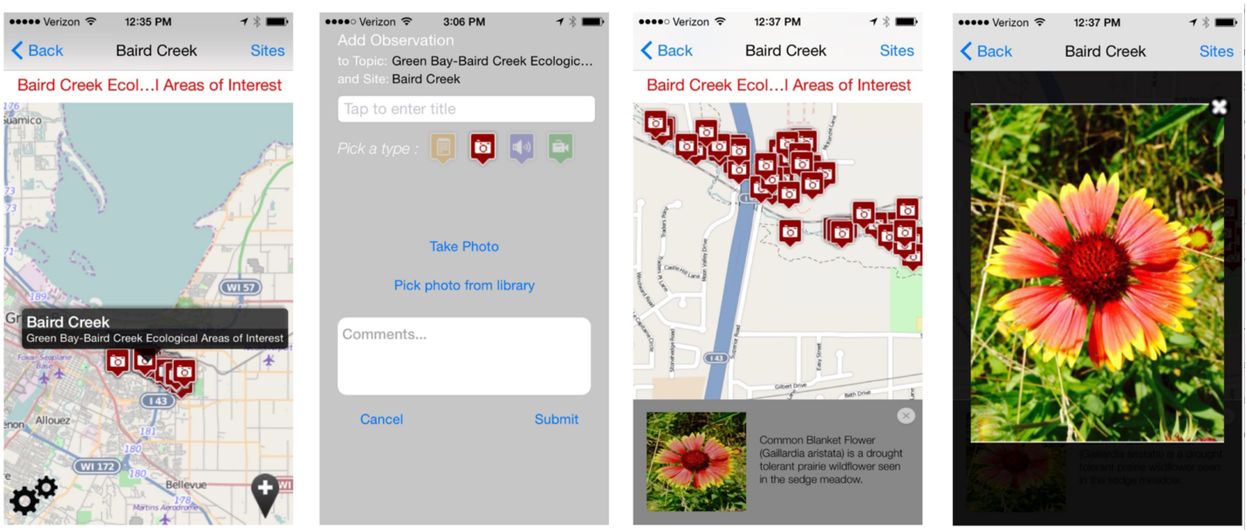


Figure 2. Screen grabs of the mobile interface visible to users, which exemplify the place-topic-site-observation hierarchy.



A B C D

Figure 3. Screen grabs demonstrating the process of adding observational content using the mobile app. From any given topic screen (A), users select the tear-drop-shaped “plus” (+) button in the lower-right corner, which brings up the Add Observation screen (B) on which the choose the media type and add a comment. Once and observation has been submitted, it appears on the topic map (C). When a user selects an observation’s icon, its associated media is enlarged (D).

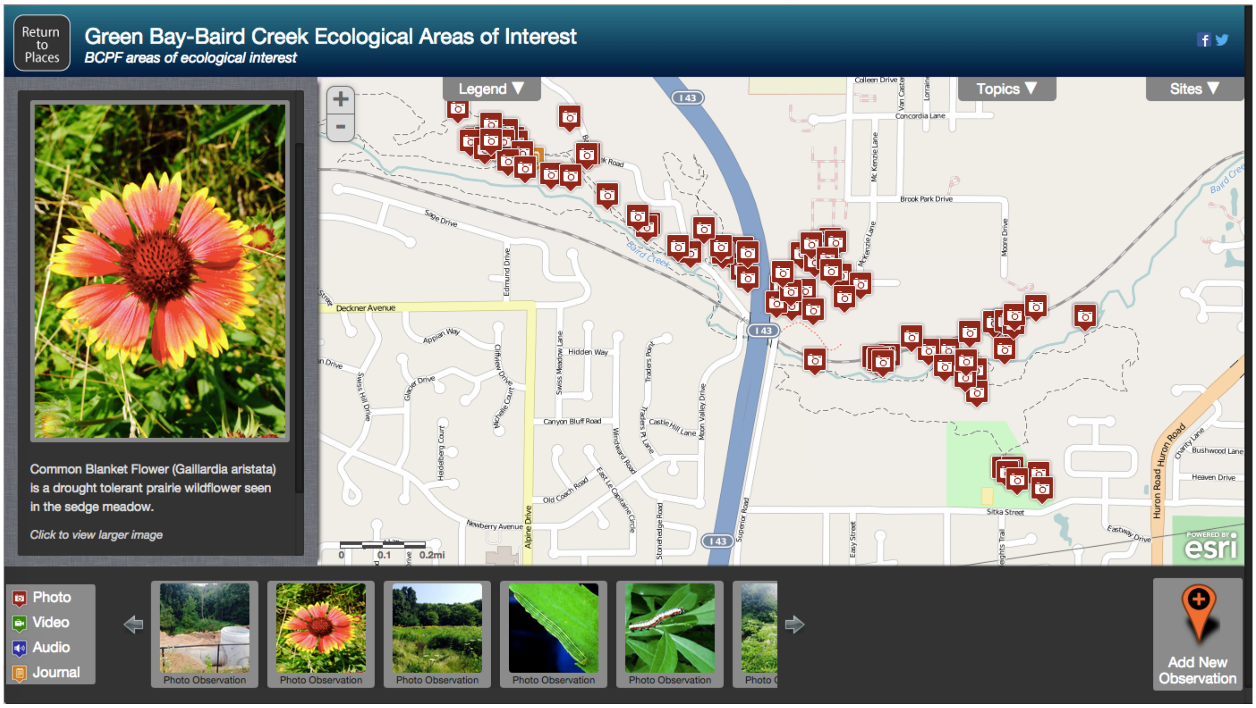


Figure 4. An example of the web application interface, with drop-down menus for topics and sites (upper right), a scroll bar displaying each site's observations (bottom), and a viewing pane (left) to browse individual observations.

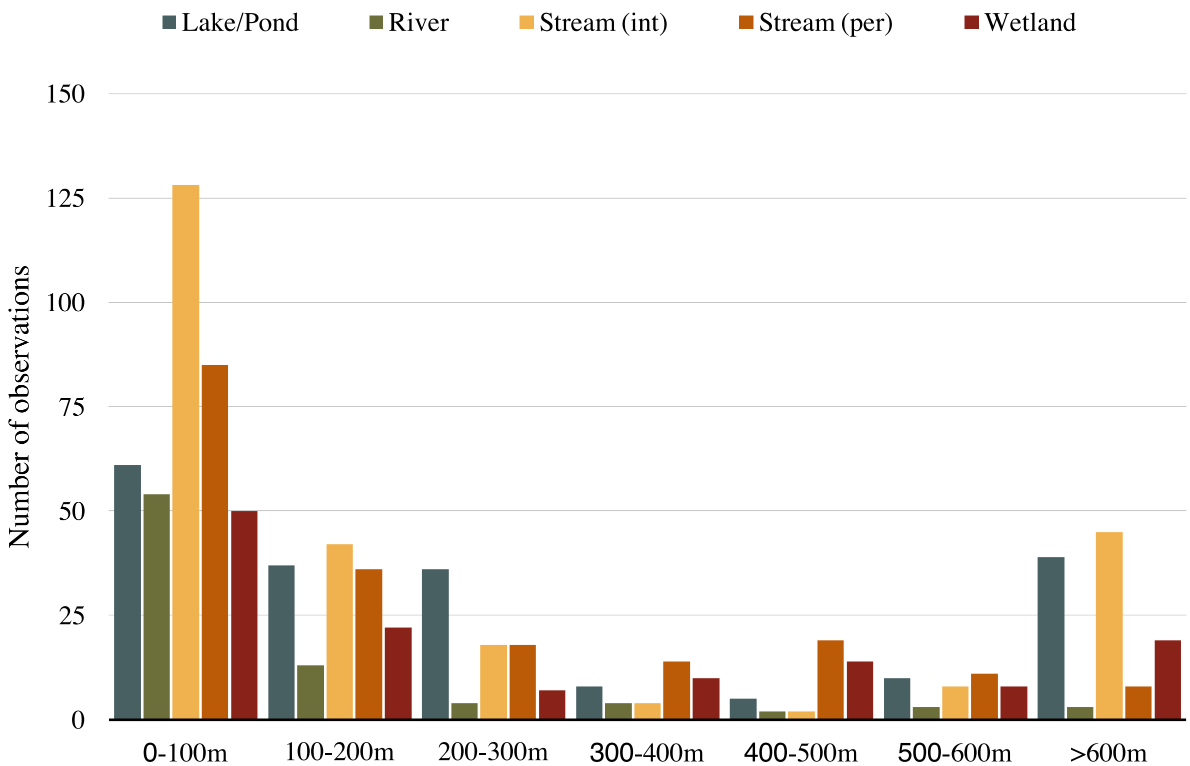


Figure 6. Distribution of observations according to the distance between an observation and its closest water feature.

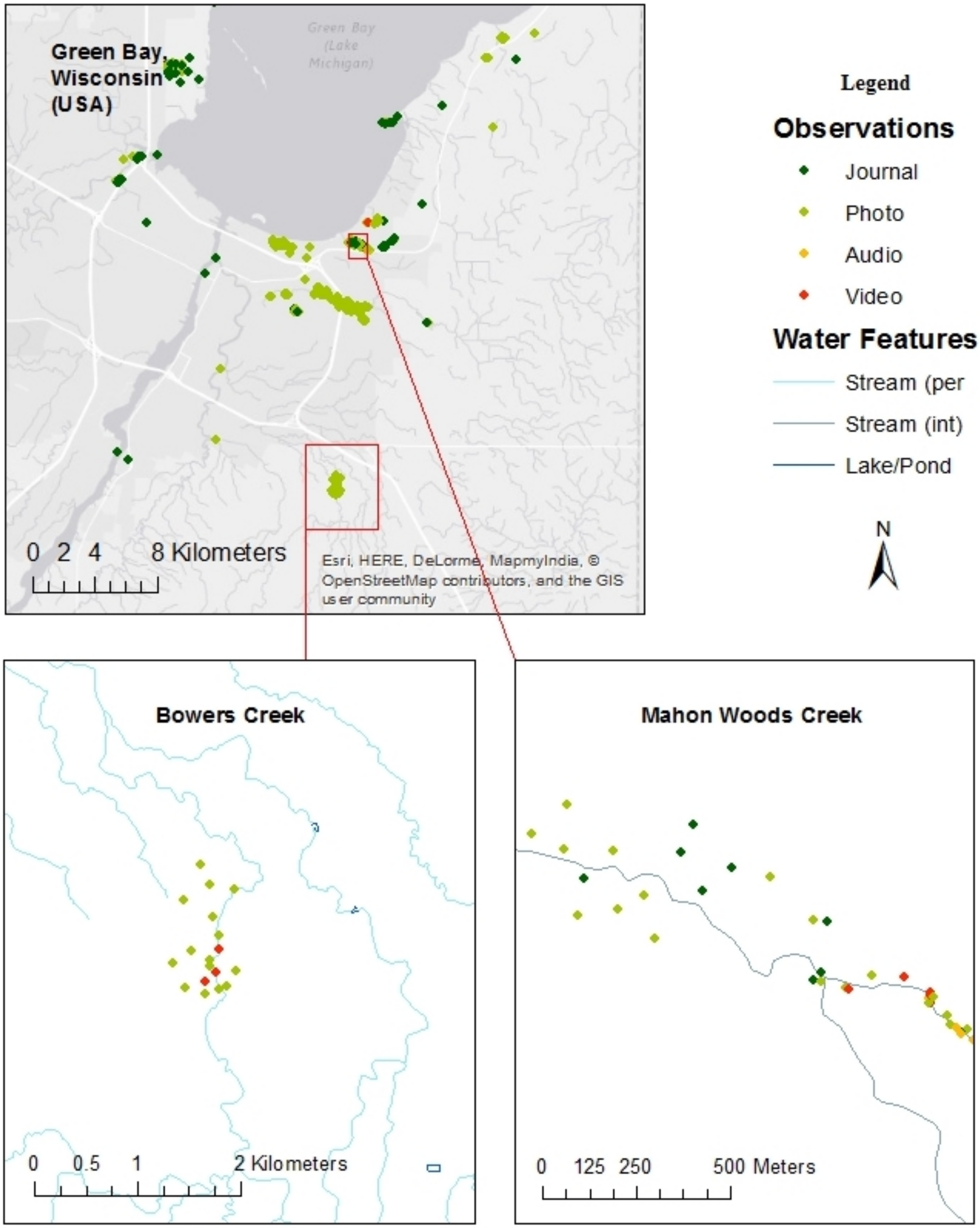


Figure 7. Maps depicting a selection of observations in the GB area, the inset close-ups of observations and their nearest water features (Bowers Creek and Mahon Woods Creek, respectively).