Polar Geography, 2014
Vol. 37, No. 1, 28–47, http://dx.doi.org/10.1080/1088937X.2013.873089

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Participatory photomapping: a method for documenting, contextualizing, and sharing indigenous observations of environmental conditions

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(*Received 3 June 2012; accepted 4 December 2013*)

The Mackenzie Delta Region of Northwestern Canada is a dynamic environment that is ecologically and culturally significant. This region is experiencing environmental change that is expected to worsen with continued climate warming and additional anthropogenic stressors. In this project, we developed and field-tested a monitoring program that used participatory photography to document local observations. Working with local Hunter and Trapper Committees and the Inuvialuit Joint Secretariat, we adapted a participatory photomapping method to document Inuvialuit observations of environmental conditions using digital cameras and GPS units. Subsequently, photo-elicitation interviews added a detailed narrative to each georeferenced observation. Approximately 150 of these observations were entered into a web-based map. Interviews with cultural experts and potential map users suggest that web-based mapping is an effective way to document and share local environmental observations and concerns. The visual and oral elements of digital multimedia also fit well with Inuvialuit culture, which is based on traditions of orally transmitting knowledge and learning by watching and doing. Overall, this research highlights the effectiveness of using georeferenced photos to document and share Inuvialuit observations and indicates that participatory photomapping monitoring programs can significantly improve capacity to detect the impacts of environmental change and contribute to northern planning and decision-making.

Introduction

Many indigenous peoples have an intimate understanding of their local environment, which they rely on for survival (Laidler *et al*. 2010; Nuttal *et al*. 2005). This multifaceted knowledge is transmitted culturally across generations and includes the following: knowledge of travel and navigation strategies, vegetation, weather, the range and distribution of wildlife, and hunting, fishing, and trapping techniques for each season (Alunik *et al*. 2003; Aporta 2009; Bandringa and Elders 2010; Cruikshank 2001; Inuvialuit Communications Society 2009; Lyons 2010). Indigenous knowledge that relates to the environment is widely referred to as Traditional Ecological Knowledge (TEK) (Berkes 2013). Despite critiques of this term (Agrawal 2009; Nadasdy 1999), we use it throughout this paper because it is widely used to refer to the 'knowledge, practice and belief, evolving by adaptive process

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and handed down through generations by cultural transmission, about the relationship between living beings (including humans) with one another and their environment' (Berkes 2013, p. 7). TEK can be extremely helpful for identifying and monitoring environmental changes and guiding environmental assessment and resource management (Armitage 2005; Armitage *et al*. 2011; Gearheard *et al*. 2011; Huntington *et al*. 2005; Kokelj *et al*. 2012; Moller *et al*. 2004; Menzies 2006; Pearce *et al*. 2009; Riedlinger and Berkes 2001; Wolfe *et al*. 2011).

Indigenous land users are particularly well positioned to contribute to environmental monitoring in the north because complex logistics and the pace of change complicate monitoring efforts (Huntington *et al*. 2005; Kokelj *et al*. 2012; Pearce *et al*. 2009; Pisaric *et al*. 2011; Riedlinger and Berkes 2001; Serreze *et al*. 2000). As such, there is a growing pressure to use TEK in northern environmental decision-making and research (Berkes 2009; Eicken 2010; Eisner *et al*. 2009; Green and Raygorodetsky 2010; Huntington 2000; Lyver *et al*. 2010; Pearce *et al*. 2009; Wenzel 1999; Wohling 2009). Despite the potential for TEK to contribute to environmental assessment, monitoring, and management, there is little available guidance regarding how to effectively and appropriately use indigenous knowledge in these contexts (Usher 2000). TEK holders themselves have also struggled with how to effectively communicate their knowledge with other stakeholders involved in these processes (Bonny and Berkes 2008). TEK exists in specific and complex sociocultural contexts, which are integral to its understanding and appropriate use (Berkes 2009; Cruikshank 2001). According to Berkes (2009, p. 151), adequately contextualizing TEK remains 'one of the biggest challenges in Indigenous knowledge research.' In some cases, TEK has been inappropriately applied to scales outside of its intended use in ways that distort or transform its original meaning (Cruikshank 2001; Wenzel 1999; Wohling 2009). The use of TEK in decision-making has also been criticized for lacking meaningful indigenous participation (Dowsley 2009; Mauro and Hardison 2000; Newton *et al*. 2005).

In the Inuvialuit Settlement Region (ISR) (Figure 1), ongoing changes in temperature, natural disturbance regimes, and industrial development are anticipated to drive widespread environmental changes. In this region, it is also a policy requirement that traditional knowledge be used in co-management and environmental decision-making (Keeping 1989; Usher 2000). The Inuvialuit Final Agreement (1984), the Mackenzie Valley Resource Management Act (1998), the Mackenzie Valley Joint Review Panel, and the McCrank Report to the Minister of Indian and Northern Affairs Canada all recommend that traditional knowledge be considered in decision-making, resource management, and assessment (Government of Canada 2005; Keeping 1989; McCrank 2008; National Energy Board 2010). In this region, there is a clear need for the development of an effective and community-driven strategy for documenting and communicating observations of environmental conditions grounded in TEK. However, at this point in time, there is no monitoring program explicitly focused on TEK.

In this research, we explored the potential of participatory photography as a means to facilitate the documentation of local environmental knowledge. Participatory photography has been widely used to identify community health concerns, promote dialog among stakeholders, and drive policy change (Baldwin and Chandler 2010; Wang and Burris 1997; Wang *et al*. 1998; Wilkin and Liamputtong 2010). Combining photo monitoring with semi-structured interviews can also provide a means of helping diverse stakeholders understand the cultural landscape, culture, and

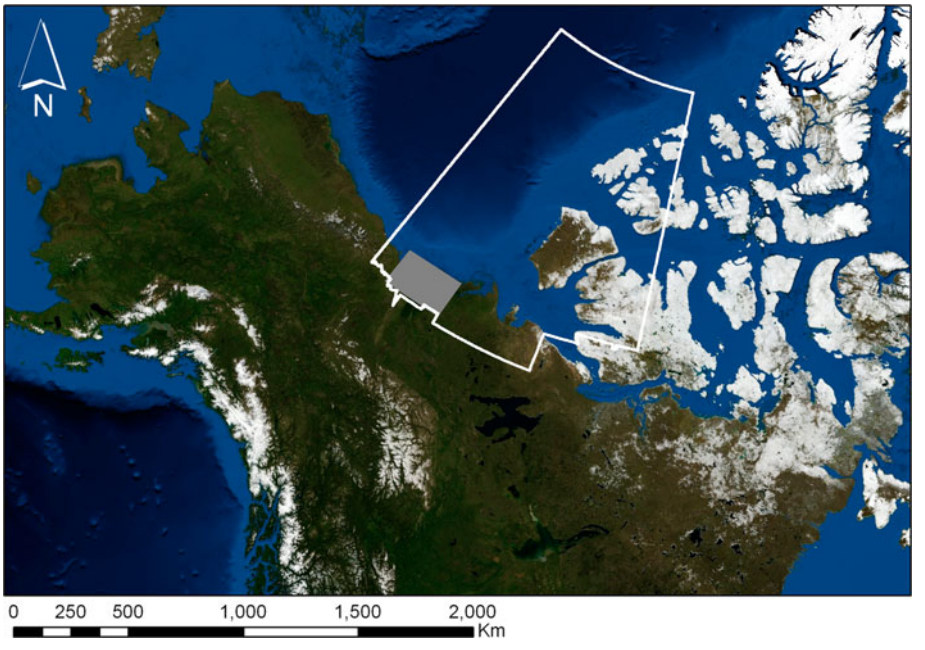

Figure 1. The Inuvialuit Settlement Region (ISR) boundary (shown in white). The gray box corresponds to the area shown in Figure 2.

worldview of indigenous peoples (Bosak 2008; Lardeau *et al.* 2011). However, to date, the use of participatory photography in environmental monitoring/assessment has been relatively limited (Berbés-Blázques 2012; Berrang-Ford *et al.* 2012). The goal of this work was to develop a strategy for documenting, and communicating local observations of environmental conditions that (1) is effective, (2) is compatible with contemporary Inuvialuit culture, and (3) can facilitate knowledge transfer within Inuvialuit communities. To accomplish this, we used a participatory photomapping (PPM) protocol to record and communicate local observations of environmental conditions (Aswani and Lauer 2006; Dennis *et al.* 2009; Mapedza *et al.* 2003). This protocol was deployed during 13 outings with 16 Inuvialuit participants from three communities in the ISR: Inuvik, Aklavik, and Tuktoyaktuk (Table 1). Semistructured interviews with nine Inuvialuit cultural experts examined the following research question: can PPM adequately communicate and contextualize Inuvialuit observations of environmental conditions in a manner consistent with contemporary Inuvialuit life? To our knowledge, this research is one of the first efforts to engage indigenous experts and youth in long-term environmental monitoring organized around participatory photography.

Methods

Developing a PPM protocol

In September 2008, the Hunter and Trapper Committees (HTC) from Inuvik, Aklavik, and Tuktoyaktuk met with researchers from the University of Victoria[2] (UVIC) and Aboriginal Affairs and Northern Development Canada (AANDC) to discuss the development of an environmental monitoring program utilizing the

Table 1. Inuvialuit land users, youth, and cultural experts who participated in the (2010) pilot project.

Inuvialuit participant	NWT community	Brief description	PPM participant	Evaluated PPM protocol
Adam, Emmanuel	Tuktoyaktuk	Inuvialuk hunter and trapper, Pastor, former member of the Tuktoyaktuk Hunter and Trapper Committee (THTC)	✓	✓
Allen, Terrance	Aklavik	Inuvialuk youth	✓	
Amos, Jordan	Inuvik	Inuvialuk youth	✓	
Archie, Billy	Aklavik	Inuvialuk hunter and trapper, founding director of the Aklavik Hunter & Trapper Committee (AHTC), contractor	✓	
Arey, Joe	Aklavik	Inuvialuk elder, hunter and trapper	✓	
Arey, Nellie	Aklavik	Inuvialuk elder, hunter and trapper	✓	
Binder, Richard	Inuvik	Inuvialuk hunter and trapper, Inuvialuit Joint Secretariat		✓
Esagok, Douglas (Joe, Dougie)	Inuvik	Inuvialuk hunter and trapper, Inuvialuit Game Council Chair, Inuvik Hunter and Trapper Committee (ITHC) member, Northern Ranger	✓	
Felix, Cody	Inuvik	Inuvialuk youth, hunter and trapper	✓	
Felix, Cole	Inuvik	Inuvialuk youth, hunter & trapper	✓	
Felix, Dustin	Inuvik	Inuvialuk hunter and trapper	✓	
Gordon, Annie B.	Aklavik	Gwitch' in Elder, Interviewer for Arctic Borderlands Knowledge Co-op, language expert		✓
Gordon, Danny C.	Aklavik	Inuvialuk elder, AHTC member, Wildlife Management Advisory Council (Yukon, North Slope) member, hunter and trapper		✓
Gruben, Chucky	Tuktoyaktuk	Inuvialuk land user, former HTC member, contractor	✓	
James, Edward	Aklavik	Inuvialuk youth, hunter and trapper, traditional Inuvialuit drummer & dancer	✓	
Lennie, Edward	Inuvik	Inuvialuk elder, former member of the IHTC	✓	
Lennie, Jeanie	Inuvik	Inuvialuk elder, and land user	✓	
Floyd, Kevin	Inuvik	Youth leadership coordinator, hunter & trapper		✓
Paul, William	Aklavik	Inuvialuk youth, hunter and trapper	✓	
Pokiak, Charles	Tuktoyaktuk	Inuvialuk hunter & trapper, THTC member, contractor		✓
Pokiak, Frank	Tuktoyaktuk	Inuvialuk hunter and & trapper, Inuvialuit Game Council, former member of the THTC, hunter and trapper		✓
Storr, Evelyn	Aklavik	Inuvialuk, Wildlife Management Advisory Council (Yukon North Slope & Northwest Territories), AHTC member		✓
Storr, Lyle	Aklavik	Inuvialuk youth	✓	
Wolki, Fred	Tuktoyaktuk	Inuvialuk elder, hunter and trapper		✓

knowledge and experience of Inuvialuit land users. At this time, a steering committee, with members from each hunter and trapper committee, the Inuvialuit Joint Secretariat, AANDC, and UVIC, was established to guide efforts to develop this program. Following project initiatives in 2009, which included a meeting of knowledgeable Inuvialuit land users (experts) to discuss the issue of salt-kill in outer Mackenzie Delta, and a land-based TEK workshop in the outer delta (Kokelj *et al.* 2012), the steering committee developed the idea of using photo monitoring to record and communicate Inuvialuit observations. In the winter of 2010, members of the steering committee from UVIC and AANDC presented this idea at meetings with the HTCs from each community. During these discussions, HTC members stressed that a pilot project to document local observations of environmental conditions should facilitate intergenerational knowledge transfer (traditional and technological) between local youth, Inuvialuit elders, experts, and project researchers. To meet these goals, we developed a field-based protocol with a focus on elder-youth interactions. At meetings with the HTCs, members also identified (1) priority monitoring areas and (2) knowledgeable local participants (Inuvialuit experts and youth).

In the summer of 2010, the PPM method was deployed in and around the communities of Inuvik, Aklavik, and Tuktoyaktuk and remote areas in the ISR at sites identified by local experts. The method was used primarily with pairs of participants (Inuvialuit experts and local youth), but other PPM outings involved groups of participants with multiple experts and youth, or a single expert. To facilitate the PPM procedure in this pilot project, we accompanied participants to all sites out on the land. At each observation site, Inuvialuit experts described their observations and shared detailed knowledge about the site. Youth participants worked with the expert to photo document the observation with a Olympus (Stylus Tough HD6000) digital camera. Landscape, mid-range, and close-up digital photographs were taken from a variety of angles to document the site. The digital cameras were set to take the highest quality JPEG photographs possible (10 megapixels). To encourage the youth to take photos and provide 'back-up' images, additional photos were taken with a Nikon (D90) camera at each site. Back-up photos were taken for deliberate redundancy, in case digital files or metadata were damaged or lost, or in the event that errors occurred during georeferencing. Since youth training was one of the core goals of this program, we used handheld GPS units (Garmin GPSMAP 60CSx) to assist navigation during PPM outings and to record the location of photo and video observations. GPS units recorded a track log for the duration of each outing, and coordinates of each photo observation were obtained using HoudaGeo. This software program estimates the geographic location of each image by linking the photo's time signature (found in its metadata) with the coordinates from the corresponding time on GPS track log.

Photo-elicitation interviews

Following field work, photo-elicitation interviews were used to record detailed participant observations about each site. Prior to each interview, participants reviewed the photos they had taken and selected up to 60 key images. To provide a focal point for the interview, these images were shown to the participants on a laptop computer. During interviews, participants provided a detailed account (a photo narrative) to accompany each photograph. Interviews were recorded using a digital audio recorder (Zoom H2), and subsequently transcribed. Photo-elicitation

interviews were conducted in two different settings: (1) with the expert in their home, after returning from the PPM outing and (2) out on the land in the Aklavik hunter and trapper cabin with a group of four experts. In both cases, photos were reviewed on a laptop computer. Participants were compensated for their time using locally established rates. All participants agreed to have their observations shared publically and gave us permission to use interview materials in research publications. In 2011, participants were given the opportunity to review their observations in person or online.

Mapping participant observations

Each PPM outing produced a suite of observations that included digital photos and videos, and a photo-elicitation interview (digital audio file and a written transcription), and a GPS track log. A file-naming convention was created for each PPM site to assist with file handling and web-based mapping. In the fall of 2010, participant photos, video, and interview transcriptions were organized in a Drupal geodatabase and web-browser (Figure 2). Drupal is a web-based open source content management systems used in community-based mapping (Weiss and Lorenzi 2008). Drupal was chosen instead of a program such as ArcGIS because it is free and is highly customizable. In this project, we used Drupal to overlay photos and associated text, over satellite imagery displayed in Google Earth. This provided a simple means to store and share the mapped data with viewers (Fonseca and Vieira 2008). Subsequently, all the information collected as a part of the photo-monitoring process was organized and imported into a Drupal as a comma separated value ('.csv') file. Each 'data point' in this file consisted of a digital photo file name, latitude, and longitude (X, Y coordinates of the image), author (observer), observation type (theme), description (verbatim text from the photo-elicitation interview), and a 'should this be mapped?' field.

Assessing the protocol

To assess the capacity of the protocol to situate Inuvialuit observations of environmental conditions in the context of Inuvialuit culture, we consulted 10 cultural experts. Participants in these interviews were identified during the course of fieldwork and in consultation with local hunter and trapper committees. Only one of these individuals participated in our 2010 fieldwork, using the PPM method. Semistructured interviews were conducted with Inuvialuit experts in the communities of Aklavik, Inuvik, and Tuktoyaktuk, Northwest territories, and one interview was completed over the phone. Participants were asked to review the website, read the brief project description on the home page, and navigate the observations recorded there. The basic layout of the map (geobrowser) and the functions of the map were described and demonstrated and then participants were asked to spend up to 15 minutes navigating the map of observations by zooming into particular areas of interest, visiting observation sites, and entering keywords of their choice into the search bar. Three interviews were conducted without Internet access because a winter storm had disrupted all telecommunications. In these cases, a standardized presentation including screen shots of key geobrowser features, functions, and examples of observations was shared with the participants.

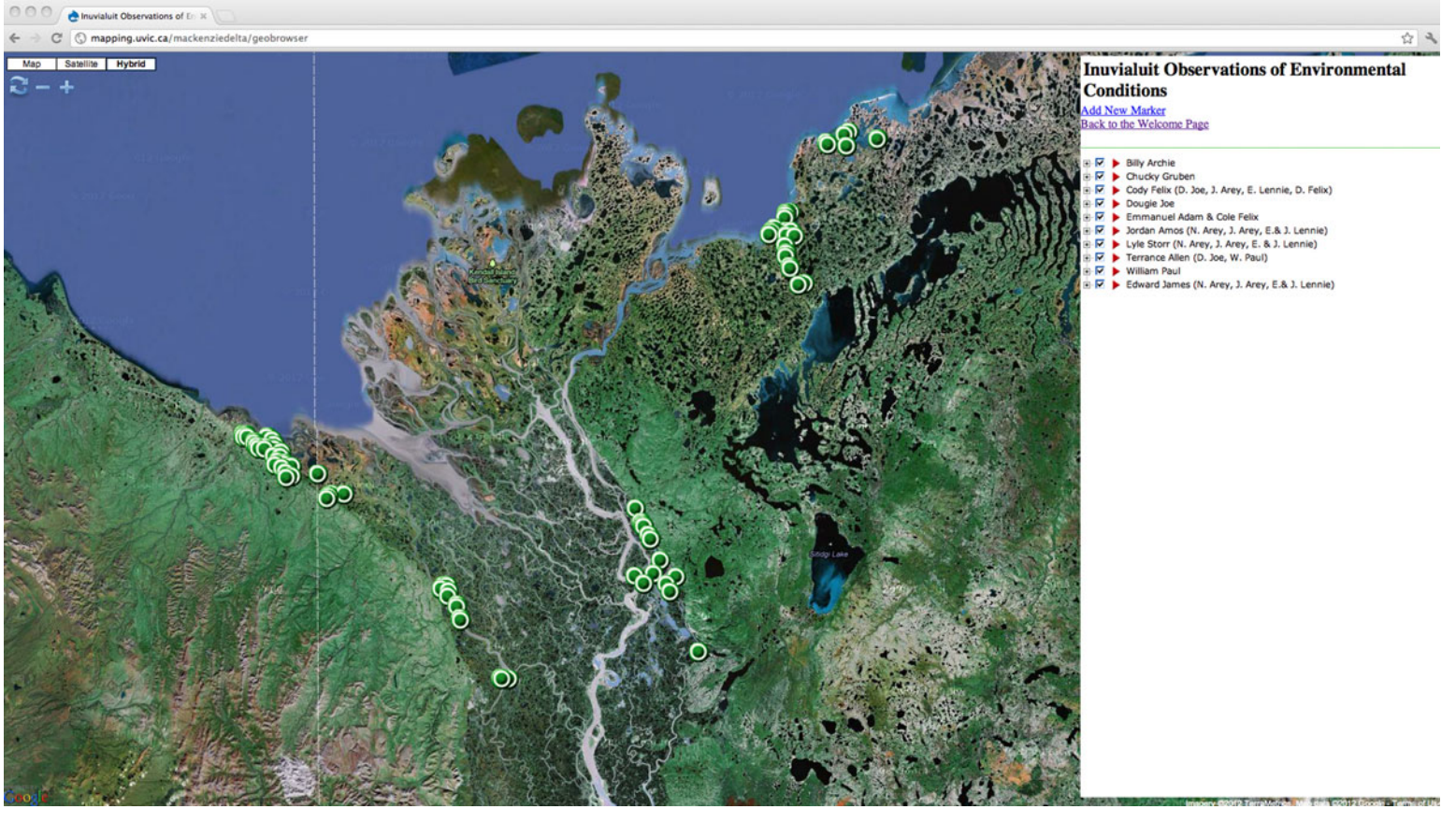

Figure 2. Screen shot of the geobrowser showing participatory photomapping (PPM) activity in the Mackenzie Delta Region in 2010. Green circles represent individual georeferenced observations made during 2010 PPM activities in the Inuvialuit Settlement Region. Georeferenced photographs were taken at sites chosen by Inuvialuit experts. On the right side of the web-browser the observations are organized according to the Inuvialuit experts who made each observation.

After reviewing the map and its functions, participants were asked a series of questions pertaining to the utility of the map. Interview questions also sought to explore if and how the PPM method and web-based map could adequately contextualize Inuvialuit knowledge in a way that is useful for future generations of Inuvialuit. Interview participants were compensated for their time using locally established rates.

Interview analysis

Interviews with cultural experts and the photo-elicitation interviews were examined for recurrent themes using a qualitative analysis software package (Nvivo 8) to identify the number of times thematic categories were referenced by participants. Transcripts were coded descriptively using 33 themes, which were organized into higher-level categories intended to reflect the type of environmental observations. Examples of higher-level thematic categories included the following: harvesting site, coastal erosion, berry harvesting, navigation, slumping, etc.

Results

Monitoring environmental conditions

Outings conducted in 2010 with 16 Inuvialuit participants produced 151 observations, which were grouped into 33 thematic categories and entered into a web-based geo-database.[3] In some cases monitoring was conducted with a single expert, and in other situations, we worked with teams of elders/experts and youth. Experts were all active land users, and many were active members of local Hunter and Trapper Organizations and Inuvialuit co-management boards.

Many participants focused their monitoring on environmental changes including shifts in wildlife and vegetation (range and distribution), drained lakes, thaw slumping, landslides (Figure 3), river bank erosion (Figure 4), increased run-off, increased overflows, changes in permafrost, as well as increasingly hazardous conditions encountered while traveling or accessing hunting and harvesting areas (changes in water levels, increased wave action, etc.). Many of the changing environmental conditions had damaged, or threatened infrastructure (roads, cabins, camps, and buildings), important historical sites (traditionally used camps, travel routes, and grave sites), and harvesting areas. Harvesting of country foods such as plants, berries, fish, and waterfowl was also documented using photos and video (Figure 5). Other participants described how Inuvialuit land users have adapted to changes in the environment (sea ice, water levels, and drained lakes). Since observations were only made in part of the Mackenzie Delta Region, they represent a subset of the environmental changes occurring in the ISR.

Documenting and communicating Inuvialuit TEK

PPM participants and cultural experts all agreed that the PPM protocol was a good strategy for documenting and communicating local observations and concerns. Many participants attributed the success of the protocol to the use of photography (the visual medium), the photo interviews (storytelling), time spent on the land traveling and observing (in situ), and the paring of local youth and elders/experts.

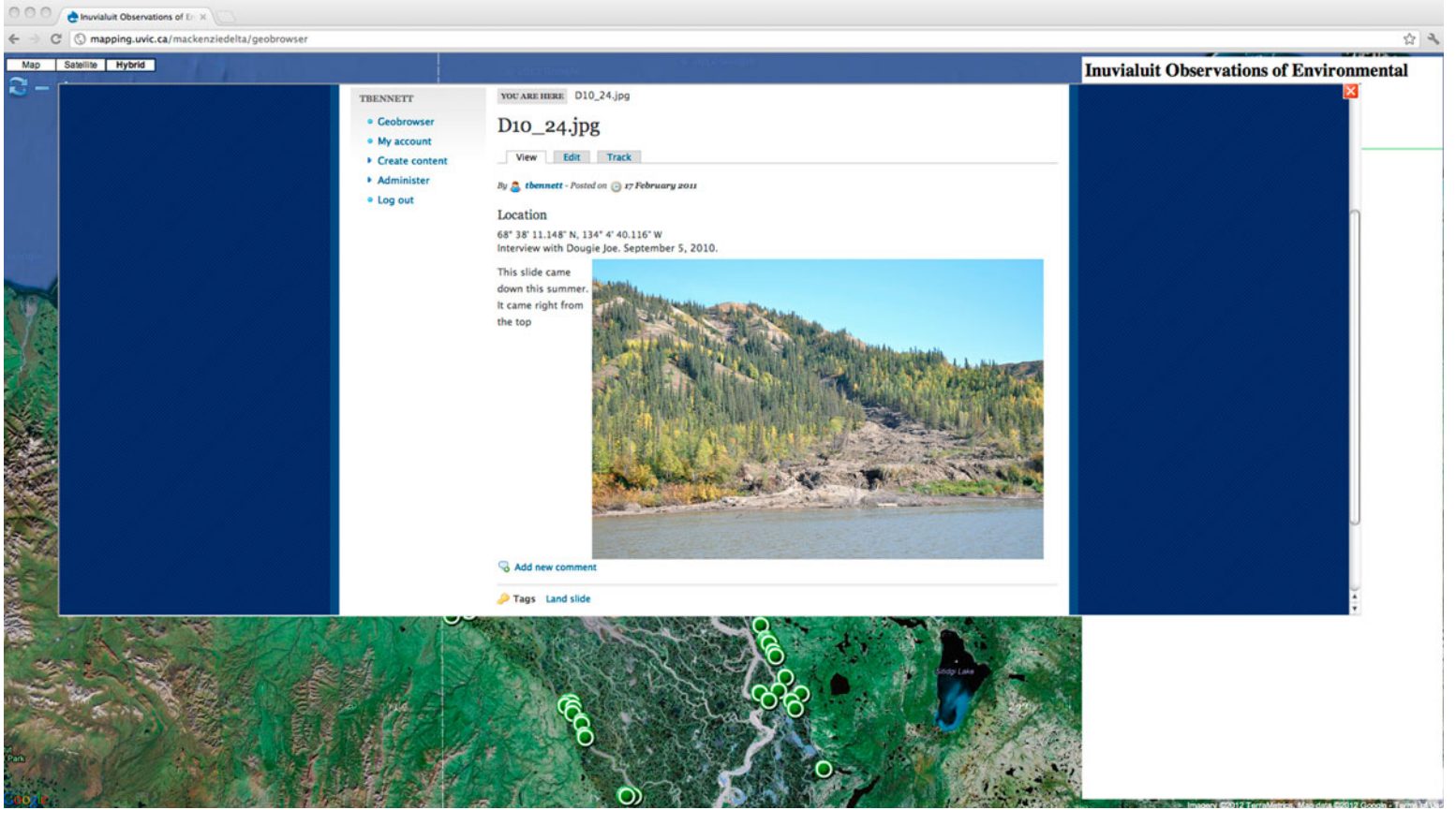

Figure 3. Photograph showing an observed landslide that occurred in 2010 in the Caribou Hills, north of Inuvik, NT. Observations in the geobrowser include the GPS coordinates of the photo, the date, the name of the observer, and a direct quote from the photo-elicitation interview that corresponds to the photo.

Figure 4. Three photos taken by an Inuvialuk youth (Jordan Amos, Inuvik) were merged into a panoramic image. This photo documented riverbank erosion on the Mackenzie River near Inuvik. Inuvialuk expert Douglas Esagok noted that riverbank erosion is occurring at a rapid rate, requiring that these cabins be moved every 2 years.

> You got to be out there to see it. I mean if you stay in town, all you hear is stories about this happening and that happening. Until you finally see it for yourself, it becomes reality. You can say it's changing. Even from my own observations, from my own travels, things have really changed. And it's getting faster and faster because of the warming, because of the melt. Things are changing pretty fast now. (Emmanuel Adam)[4]

> I think it's a good way. I think it's important that we start recording these observations from people [local land users] who go out on the land. (Frank Pokiak)

> I think it's a good way because it's visual, if you have this and you can show the elders or the young people what has been collected by using this method, I think it becomes more real to them, then just having a document in a binder type form. It is a good approach, and with the technology today I think young people will have more interest in gathering information. (Evelyn Storr)

Participants noted that organizing the environmental changes observed by land users on a web-based map of the region could also help land users explain and communicate their observations to others.

> I mean it's a good way [PPM method] because people can literally see the changes that do happen over time. It's real; you can see the evidence of it. To see the actual pictures … explaining it, it's so real. (Emmanuel Adam)

> If you had it on a website where people can actually look at it and see the changes that they are talking about, I think a lot of the time we really have a hard time trying to express ourselves and [describing] these changes, you know because you don't have any evidence of them. (Frank Pokiak)

> It may come in handy down the road, as we try to express ourselves as to why these areas are important to us. If people could take note of which areas they use for hunting and why, why it's important to us. Even for camping. I think it may be a good thing to do, especially with lots of pressure from oil and gas. (Frank Pokiak)

Many participants also expressed concerns regarding the loss of TEK, stressing that it must be accurately documented and shared, and highlighting the importance of local information and knowledge about the land, environmental changes, and

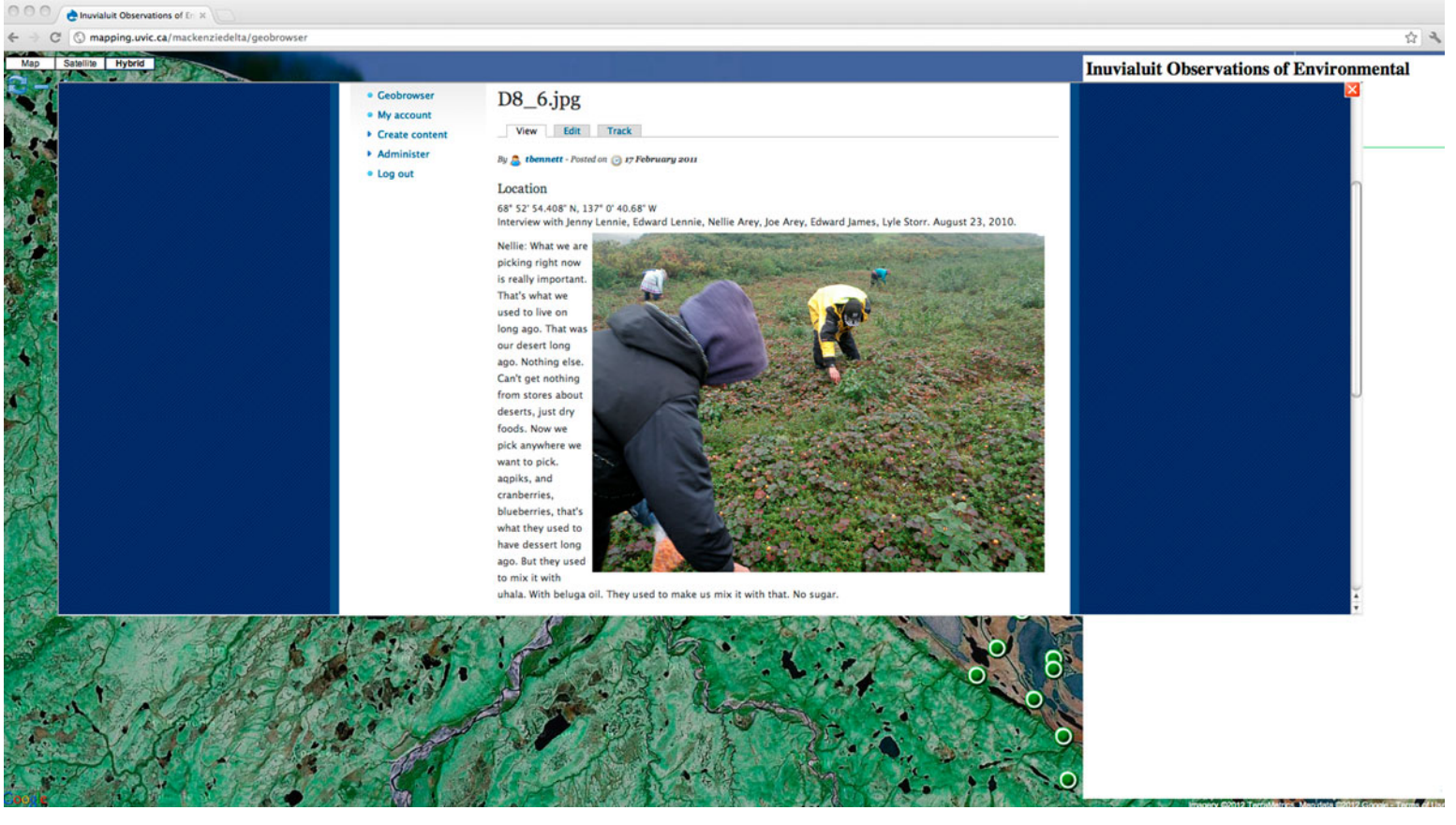

Figure 5. Photograph showing an observation of an aqpik (*Rubus chamaemorus*) harvesting site on the Yukon North Slope. Berry harvesting continues to be an important Inuvialuit activity. In the text from the photo-elicitation interview (left of the photo), Nellie Arey describes the cultural importance of aqpiit harvesting and how these berries were traditionally mixed with uhala (beluga oil).

traditional hunting, trapping, camping, travel, and harvesting techniques. Local interest was also expressed in documenting and archiving such expert knowledge and facilitating its transfer to youth and between northern communities.

> I think it's a really good way to pass down information, we are going into a different technological era. 50 years ago we didn't have anything like this, and our youth are well into it, and they are going to be our future leaders. (Richard Binder)

> We are a people that travel, and we are a people that observe and that use the land … Our culture is to observe and go places. Pass on the information to others who you know frequent these places. It's really important. (Emmanuel Adam)

Several interview participants noted that the PPM protocol might help to alleviate an experience they described as 'research fatigue.' By providing a more accessible form of information sharing, the web-based PPM can archive local observations, knowledge, and local concerns online so that northern researchers can access information about the community prior to arriving in the communities. The effectiveness of this strategy however, is dependent on long-term website maintenance.

> There needs to be data sharing, and knowledge about what's going on [community concerns], and to me that's going to lessen the impact [time commitments] on the community. (Richard Binder)

> Over the years a lot of community members seem to have developed this fatigue to research and to supporting researchers. (Kevin Floyd)

Figure 6. Emmanuel Adam and Cole Felix on a participatory photomapping (PPM) outing, photographing retrogressive thaw slumping, west of Tuktoyaktuk, NT. In 2010 Inuvialuit experts and youth photo mapped 151 observations of environmental conditions in the Mackenzie Delta Region. Photo: T. D. Bennett, 2010.

Effective PPM pairs

We found that the PPM pilot project worked better in some contexts than others. The most effective PPM outings occurred with small groups that included an engaged youth and a knowledgeable and interested elder or expert (Figure 6). Working with the same pair on multiple outings also increased their engagement in monitoring activities over time. In some cases, working with a single expert observer was also very effective. Large groups were generally more difficult to work with because of the increased complexity of travel logistics, and reduced opportunity for 'one-on-one' PPM facilitation.

Sensitive observations

During photo-elicitation interviews, Inuvialuit experts identified some observations as sensitive and stressed that they should not be made public. For example, along a rapidly eroding portion of the Beaufort Coast, PPM monitors noted a recently exposed Inuvialuit gravesite that was about to be washed out to sea. The site was photographed from a distance. Participants acknowledged that while it is important to document the loss of historical sites to rapid coastal erosion, identifying the specific locations of gravesites was problematic. Historically the Inuvialuit were buried with all of their possessions and these sites could become the sites of artifact theft. Similarly, other participants identified excellent harvesting sites (productive berry plots or fishing/hunting areas) as areas that are important to identify for planning purposes, which they indicated should not be identified on a public map.

PPM in education

A number of participants suggested that the PPM protocol could be integrated into school programs and into the Inuvialuit cultural resource center. Participants also suggested expanding the scope of the protocol to include other communities in the ISR, as well as areas outside of the ISR.

> I think it would be excellent within the resource center, because with education now, and northern studies and the Aboriginal programs, if this is available, all the schools have computers and they have smart boards, you can just pull information if you have the site, you could show the kids. Say the youth that were involved, I mean that could be a real good show and tell project when they go back to school, and they can use something like this with their studies. (Evelyn Storr)

> You need to start working with the schools. They have equipment there. They could do monitoring around the area. They can see it for themselves, it's something I've always tried to encourage. There are a lot of bright young kids there, and with the right tools for the science teacher it could have potential. You are combining what the local elders know about the area with science and that's the way to monitor impacts, especially climate change. (Billy Archie)

Discussion

In this pilot project, we used a combination of participatory photography, photo-elicitation interviews, and web-mapping to document and communicate Inuvialuit

knowledge of environmental conditions. Collectively, these strategies offered great flexibility. Photography provided a simple and effective focal point for communication that was easily combined with geospatial information, storytelling (photo-elicitation interviews), travel, and time spent on the land. Spending time on the land has been a fundamental part of Inuvialuit culture and survival for thousands of years (Alunik *et al.* 2003; Inuvialuit Communications Society 2009). Integrating monitoring activities out on the land, while traveling, observing, and sharing knowledge about the environment through storytelling and experiential learning, was integral to the success of our monitoring protocol.

We used the PPM approach because it is an appropriate strategy for documenting and disseminating TEK, a form of knowledge that can be difficult to visualize and contextualize (Bonny and Berkes 2008; Dennis *et al.* 2009; Fox 2003). We found that visual and multimedia techniques have great potential to assist with effective communication and dissemination of TEK. PPM brings together observer photos, videos, and verbal observations in an interactive web-based map. In our web-based map, each photo and video observation was linked with additional information including verbatim text from the photo interview with the observer, the observer's name, and other details such as the date, time, and exact location the observation was made. The additional information reduces the potential for misinterpretation and the possibility that information is taken out of its intended context. We documented TEK, using visual and oral communication methods instead of written forms, to encourage participation and to avoid barriers associated with literacy or language. The visual and oral elements of digital multimedia fit well with Inuvialuit culture, which is based on traditions of orally transmitting knowledge and learning by watching and doing (Gearheard 2005; Pulsifer *et al.* 2010). Avoiding research methods that discourage participation is important when working with indigenous peoples where language and knowledge has traditionally been transferred through oral histories, not through written communication (Gearheard 2005; Gabhainn and Sixsmith 2006).

Local monitors in this research project were trained to use digital cameras as a tool to illustrate environmental conditions. While cameras offer a powerful mechanism to communicate information about the environment, it should also be noted that they provide a distinct way of seeing the world (Dennis *et al.* 2009; Yamashita 2002). To ensure that the photos they captured accurately conveyed their perspective, Inuvialuit experts were asked to choose a subset of the photographs taken during the outing. The use of semistructured interviews also created an opportunity for monitors to provide details and context 'beyond the frame' of the image.

In the ISR, previous efforts to record Inuvialuit (and Gwitch'in) observations of environmental conditions have been based on interviews and surveys with local experts conducted through the Arctic Borderlands Ecological Knowledge Co-op monitoring program (Gordon *et al.* 2007). These interviews are conducted by a single community monitor and synthesized annually in a report. This approach has documented a wealth of general information characterizing environmental conditions, but it has also been criticized for being overly general, and not recording specific locations, dates, observers, or providing additional contextual information (Folliott 2005). The PPM protocol has the potential to build on the success of the Arctic Borderlands program by adding spatial accuracy, additional observer context, and increasing the accessibility of information. Recording observations at

specific sites out on the land was also recommended by Tobias (2009) who explained that the richness of people's descriptions and memories of a particular place are enhanced when they are at a site, compared to asking people to recall such memory while in front of a map.

The PPM method also provided a partial solution to the problem of the decontextualiztaion of TEK. In this project, PPM was used to record the details of local observations, which provided important context to each observation. Combining the date, location and author for each observation, with an open-ended narrative about the location, allowed users to include as much context as they deemed appropriate. While no single communication strategy can completely capture oral knowledge deeply rooted in culture and experience (Bonny and Berkes 2008), the inclusion of narratives, place names, traditional use, and history increases the fidelity with which cultural knowledge is recorded. The PPM method also contributes to an online archive of photos of that can be used as a baseline against which future change can be measured.

Another key aspect of the PPM method identified by the Inuvialuit cultural experts was the elder–youth interaction on the land, and the opportunity for knowledge transfer and interaction in a culturally appropriate context. Participants noted that the combination of the 'hands on' outdoor approach and the focus on intergenerational knowledge transfer effectively facilitated youth engagement in Inuvialuit cultural activities. Several participants also suggested that the PPM method should go into school programming, where elders and youth could work together to document local observations, and the youth could earn class credits. School resources (teachers, funding, access to cameras, computers, 'smart boards,' and GPS units) were also highlighted as having potential to help sustain PPM monitoring efforts. Kevin Floyd noted that PPM could be important for youth because 'it gives [the youth] an investment, a very permanent and tangible connection to their future and what's at stake up here.'

The stewardship of TEK also requires protecting knowledge and the knowledge holder from inappropriate use. Other research initiatives have documented indigenous observations of changing climate conditions and shared the observations publically with wide audiences (Huntington *et al.* 2005; Krupnik *et al.* 2010; Kunuk and Mauro 2010). In this project, there were several observations made that are not appropriate for public dissemination. These included the following: (1) the location of historic grave sites that may be of interest to collectors, and (2) the identification of sensitive hunting, or harvesting areas. To ensure that TEK is not unfairly appropriated, misused, or exploited for profit without the consent of the knowledge holders, it is vital that the intellectual property of knowledge holders be protected (Brody 2010; Munzer and Raustiala 2009). To address these issues in this project, observations of gravesites and sensitive harvesting sites were removed, and prior to entering the web-based map, users must agree to several terms of use, designed to protect the knowledge and its holders. Once users agree to the terms of use (check box), the site administrator provides them with a user name and password to use the web-based map. It is clearly stated on the website that the information in the web-based map is intended to communicate local observations of environmental changes to other northerners and is not to be used for commercial purposes. A statement was also added to the website, indicating that all knowledge, observations, and subsequent additions to the knowledge are the property of the observer and are managed by the Inuvialuit Joint Secretariat. In the future, observations deemed

inappropriate for the public, as well as any with potential commercial applications, will not be shared publicly. This decision reflects our belief that the best way to protect culturally sensitive knowledge or knowledge with commercial value is to keep it out of the public domain.

Our pilot project also indicates that the PPM method could be used to record other aspects of traditional knowledge. For example, the PPM protocol could be used to organize and communicate: place names, traditional song and dances, traditional narratives, indigenous language, and traditional skills and practices. Other examples include travel routes and the locations of lakes used for drinking water. If the PPM protocol is deployed to record these types of knowledge, communities will need to consider safe and secure information storage and user access controls.

Despite the effectiveness of pairing youth and elders, there were several challenges. The majority of community monitors participating in this project in 2010 were men. Consequently, observations made in the first year of this project provide a gendered perspective on environmental conditions likely focused on environmental conditions and environmental observations related to male activities. A comprehensive perspective on environmental conditions requires the perspective of female land users/elders, which would likely reveal a distinct set of environmental observations (Williamson *et al.* 2004). Slow Internet connection speeds, a complex web-based mapping interface, and technical demands of managing and organizing georeferenced multimedia observations are key challenges that will need to be overcome before the PPM protocol can be implemented widely.

Conclusion

Inuvialuit land users have an intimate and detailed understanding of environmental conditions in the Mackenzie Delta Region and are well suited to monitor environmental change. This research highlights the effectiveness of using visual and participatory methods to document, contextualize, and share this knowledge. Our research suggests that the PPM protocol is effective because it is compatible with Inuvialuit culture and the traditions of storytelling, traveling, and observing the land, and learning by watching and doing. The combination of experiential, visual, oral, and spatial information can assist with the documentation and communication of TEK, and has potential to facilitate knowledge transfer among northern communities and build local capacity to monitor, understand, and communicate environmental changes. Our work provides a web-based solution for archiving and sharing local knowledge in a standardized format. There is great potential within the local sphere for PPM to be adopted and sustained in the North. For northern community members, PPM could be comprehensively utilized in a certain geographical area, under the control and ownership of local peoples, sustained through integration with local school programming, and supported by effective research and community partnerships. Ultimately, the success of a long-term PPM initiative will require community ownership of the process, and ongoing and effective collaboration between community members, community organizations, and university researchers.

Acknowledgments

This project would not have been possible without the assistance of key individuals and organizations. The authors would like to thank: Emmanuel Adam, Richard Binder, Douglas Esagok, Charles Pokiak, Billy Storr, Hannah M. Roessler, Michelle Gruben, the hunter and

trapper committees of Aklavik, Inuvik, and Tuktoyaktuk, the Inuvialuit Joint Secretariat, and the Cumulative Impact Monitoring Program (CIMP). Steve Kokelj, Claire Marchildon, and Stephan Goodman provided assistance facilitating fieldwork.

Funding

This research was made possible by funding from a Northwest Territories CIMP grant, a MITACS Accelerate Internship, an NSERC Discovery Grant, Northern Scientific Training Award Program, an Aurora Research Institute Fellowship, a Dairy-land Environmental Scholarship, and a University of Victoria Graduate Student Award.

Notes

1. tdb@uvic.ca
2. Licenses obtained as a part of this research included: an Inuvialuit Land Use License (ILA10TN011), a Northwest Territories Scientific Research License (14795), a Yukon Scientists and Explorers Act License (10-61S&E), and a UVIC Human Research Ethics Board Certificate of Approval (10-259).
3. Observations made during the pilot year are organized along with observations made between 2011 and 2013 in an updated website: http://inuvialuit.kwusen.com
4. The quotations used in this manuscript were taken from the verbatim transcripts. In some cases emphasis was added using square brackets.

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