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Chapter 5
Communicating and co-producing information with stakeholders: Examples of participatory mapping approaches related to sea level rise risks and impacts

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Abstract

This chapter discusses practical approaches for using participatory mapping as a tool to visualize and communicate sea level rise (SLR) and climate change risks, to share information about the vulnerability to, and threats of, climate change, and to co-produce knowledge with stakeholders. The examples presented in this chapter are from demonstrated applications in communities in Virginia (USA) that involve participatory mapping and that utilize a web-Geographic Information System (GIS). The web-GIS is innovatively combined with other technologies and participatory processes to create low-cost high-tech approaches so that even people with little to no knowledge of GIS can interact with maps and can contribute to knowledge creation in the complex issues of SLR and climate change.

Introduction

Many coastal communities live under the persistent threat of extreme events due to climate change – among them are heavy precipitation, coastal flooding, storm surge, and hurricanes. Although it was previously considered an area best left to the experts, climate change is now an area in which the need for public participation has been increasingly recognized. Local knowledge is becoming critical to develop strategies to cope with and adapt to climate change issues such as sea level rise (SLR). Researchers and practitioners have adopted innovative approaches and technologies for engaging and communicating with a wide range of stakeholders and for developing local knowledge. This chapter focuses on participatory mapping as one approach to communication and engagement. It can be used to involve community members in developing spatial knowledge about SLR and climate change.

Participatory mapping, which encompasses any process in which individuals share in the creation of a map (Goodchild, 2007), emerged around the 1990s (Chambers, 2006) and it has since expanded in complexity and technological sophistication, particularly since the advent and growth of the Internet and the World Wide Web (Rawat & Yusuf, 2019). As web-based technologies have evolved, geographic information systems (GIS) are increasingly used in participatory mapping.

The purpose of this chapter is to describe how participatory mapping can be used to visualize and communicate the risks and impacts of climate change, and SLR particularly, and to co-produce, with stakeholders, information about their vulnerability to the threats of climate change. This chapter begins with a theoretical discussion of participatory mapping. Next, it presents how participatory mapping supports both climate change communication and stakeholder participation, particularly in creating usable local knowledge. This discussion is followed by two in-depth examples of the application of participatory mapping to share and to co-produce knowledge related to SLR.

Participatory Mapping

Participatory mapping can be defined as “the creation of maps by local communities – often with the involvement of supporting organizations including governments (at various levels), non-governmental organizations (NGOs), universities, and other actors engaged in development and land-related planning” (International Fund for Agricultural Development [IFAD], 2013, p. 4). Participatory maps are characterized by the inclusive process used to develop the map, an outcome that is relevant for the community’s needs and use, and the creation of content that reflects local knowledge (IFAD, 2013). The medium can be the ground, paper, or digitally-based GIS (Chambers, 2006). The maps that are used and created range from freehand sketch maps to georeferenced scale maps, to internet-based maps, and to multimedia maps that combine audio/video with georeferenced maps (IFAD, 2013; Reichel & Frömming, 2014).

Arthur Robinson’s research, beginning in 1950s (e.g. Robinson, 1952; Robinson & Petchenik, 1976; Robinson et al. 1977), is considered groundbreaking in its focus on improving the functionality of maps as a communication device that transfers information from the cartographer to the user of the map (Crampton, 2010; Plantin, 2014). Earlier, cartography focused on design without consideration of map use or its perception by the user (Crampton, 2010). Robinson’s work has been extended by others who have focused on improving efficiency and reducing noise in the transmission between the creators and the users of maps (Plantin, 2014). In the 1980s and 1990s, the emergence of GIS and the simultaneous criticisms of maps as accessible only to experts and professionals, prompted consideration of participatory methods and incorporation of local knowledge in GIS. This subsequently led to the development of public participatory GIS (Ganapati, 2010; Plantin, 2014). Public participatory GIS uses geospatial technology to engage the public in planning processes. The accessibility and the ease of use of web-based GIS applications, and their ability to adapt to Web 2.0, which allowed spatial data to be overlaid on existing maps like Google Earth, Google Maps, and MS Bing Maps, has led to a revolution in public participation in mapping (Miller, 2006; Ganapati, 2010; Plantin, 2014).

Participatory Mapping and Climate Change Communication

Effective communication and increased awareness about the consequences of climate change are considered crucial in climate change discourse (Harris, 2014). Correspondingly, there has been a significant amount of research regarding the use of participatory mapping in encouraging communication about and stakeholder engagement with climate change issues. Participatory mapping approaches have been used for risk assessment and disaster risk reduction planning (Cadag & Gaillard, 2012; Yen et al., 2019), for mapping stakeholder perceptions of complex environmental problems (Forrester et al., 2015), for long-term sustainable land-use planning (Frazier et al., 2010), in planning for adaptation to climate change (IFAD, 2013; Piccolella, 2013;), and for community empowerment, local development, and resource conservation (Hossen, 2016).

Participatory mapping creates “usable knowledge” or “knowledge that can improve understanding of complex environmental problems and produce effective solutions” (Robinson et al., 2016, pp. 115-116). Working with maps (1) allows people to visualize their community spatially; (2) creates a feeling of belonging and ownership (Pánek, 2015); (3) facilitates dialogue and collaboration between different members of society with different levels of access to resources, as well as differential power bases (Cadag & Gaillard, 2012; Gaillard et al., 2013); (4) improves the richness of the data gathered (Forrester et al., 2015); and (5) adds value to knowledge generation, through cooperation and social learning (Hagemeier-Klose et al., 2014). It makes complex environmental knowledge more visible and legitimate (Piccolella, 2013) and it is necessary for long-term planning in places experiencing climate change, since it can highlight discrepancies in official maps and can show actual changes over time (Pearson et al., 2017). Furthermore, participatory mapping is important in climate change communication because it offers a way to incorporate traditional ecological knowledge into new spatial understanding, generating maps that are consistent with how individuals are adapting to an increasingly harsh natural environment (Reichel & Frömming, 2014).

GIS-based participatory mapping is useful for visualizing, for integrating spatial information with local knowledge, for co-creating new knowledge by facilitating the collection and storage of information, and for supporting the joint analysis and processing of information with local stakeholders (Tripathi & Bhattacharya, 2004). For example, participatory GIS has been used (1) to examine ways to improve the resilience of communities against climate-related risks by using local knowledge (e.g. Reichel & Frömming, 2014); (2) to understand people's desires for place and for belonging (Sletto, 2009); and (3) to analyze multiple stakeholder perspectives and their underlying beliefs regarding flood management (Forrester et al., 2015).

This chapter discusses two examples from the Hampton Roads region of coastal southeast Virginia (USA) where participatory mapping approaches have been used in surfacing and codifying local experiences and know-how, in co-developing new knowledge, and in encouraging social learning. The examples in this chapter highlight the use of a combination of mapping technologies and participatory processes. The focus here is on enhancing the participatory mapping exercise for citizen engagement so that residents can identify the risks and impacts of SLR and provide community input into long-term planning. The two examples are associated with two broader engagement efforts: (1) the Action-Oriented Stakeholder Engagement for a Resilient Tomorrow (ASERT) and (2) Catch the King (CtK).

Participatory Mapping Exercises in Hampton Roads, Virginia (USA)

The Hampton Roads region is located where the Chesapeake Bay meets the Atlantic Ocean, and it has a combined population of about 1.8 million. Hampton Roads is also one of the world's largest natural harbors and one of the busiest seaports in the country. It is located within the low-lying region called the Atlantic Coastal Plain, and most of its Eastern edge is at elevations of less than 5m above sea level (Kleinosky et al., 2007). Also, Hampton Roads is experiencing subsidence, or the slow sinking of the soil (Kleinosky et al., 2007).

Hampton Roads is vulnerable to storm surge due to hurricanes which, combined with SLR and subsidence, increase the risk of inundation (UVA, 2011). These cause a sharp economic impact, from damage to public and private property to the loss of ecological resources, such as wetlands. The impact of SLR on residential properties is expected to be “$50 million annually with a SLR of .5 meters and to over $100 million annually with a SLR of .75 meters.” (College of William & Mary Law School, 2016, p.1). Another study projects that Virginia Beach assets exposed to coastal flooding in the 2070s will be valued at $582 billion (Hanson et al., 2011).

ASERT Participatory Mapping Activities

The first set of participatory mapping examples discussed in this chapter are embedded within a broader stakeholder engagement initiative called the Action-Oriented Stakeholder

Engagement for a Resilient Tomorrow (ASERT) framework. This framework was developed by Old Dominion University researchers to facilitate the engagement of stakeholders from across multiple sectors in building coastal resilience (Considine et al., 2017; Yusuf et al., 2019). ASERT emphasizes the presentation of relevant and accessible information and uses two-way communication coupled with deliberative and participatory mechanisms within an interactive or gamified environment. Participatory mapping is a fitting approach, within ASERT as it engages residents and stakeholders in codifying relevant spatial data and in developing new knowledge that can inform policy making.

In the context of ASERT, participatory mapping activities were designed to solicit and to codify residents' perspectives regarding community assets, and to help residents assess how these assets, and the communities they are embedded within, are challenged and impacted by SLR. Participatory mapping was designed to simultaneously promote social learning among participating residents by providing an interactive mechanism that promotes collaborative, joint learning and information exchange about flooding and SLR.

A demonstration project

The first application of ASERT participatory mapping took the shape of a demonstration project that used a very simple participatory mapping setup called the weTable (Mikulencak & Jacob, 2011; Messmore, 2013). The weTable served as the platform for presenting maps and data that represented the physical features of the community, as well as the impacts of coastal inundation due to SLR and/or storm surge. The goals of participatory mapping using the weTable were to facilitate residents' identification of community assets and challenges and to help them visualize the flooding impacts of SLR (Considine et al., 2017; Yusuf et al., 2018;

Yusuf et al., 2019). The spatial data co-produced with residents highlighted the impacts of flooding, such as impacts on critical infrastructure and threats to personal safety.

The weTable uses Nintendo Wii™ technology to create an interactive tabletop that allows participants to visualize SLR scenarios while simultaneously exploring and collaboratively identifying assets and vulnerabilities. As shown in Figure 5.1, a laptop computer with GIS software is connected to a projector and to a Nintendo Wii™ remote (Wiimote). The computer screen showing the map is projected onto the tabletop surface. Participants interact with the map using an infrared pen connected, via Bluetooth, to the laptop through the Wiimote. The weTable offers a low-cost electronic participatory mapping setup that uses a laptop, an LCD projector, Google Earth software (https://www.google.com/earth/), freeware, or shareware Wiimote whiteboard software, a Wiimote, and an infrared pen.

Figure 5.1: weTable set up

Source: Photos taken by K.A. Anuar

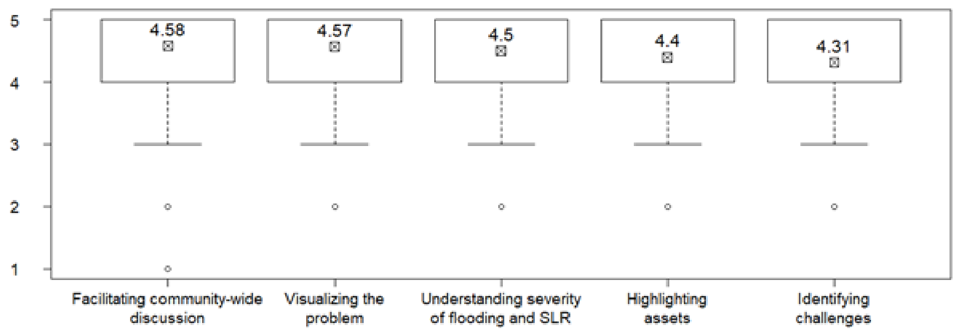
A key function of the weTable exercise was to focus participants' attention on SLR and coastal flooding by using maps to visually communicate the extent of the impacts. Participants used the weTable and the Google Earth application to interact with maps to analyze risks and vulnerabilities by indicating specific areas that might be at risk or by showing how some areas may be more vulnerable than others. Community data from participating residents and stakeholders were collected electronically via Google Earth map layers.

Participants were asked to respond to two primary questions. First, they were shown a base map of the local area and, second, they were asked to identify assets in the community, such as schools, roads, and parks. In a follow-up discussion, participants were asked to discuss the importance of these assets and how the assets should be prioritized. Participants were then shown a map overlay of a scenario involving 1.5ft of SLR and a 100-year storm surge, and they were asked to identify challenges to their community under this scenario. Through this participatory mapping exercise, local residents and stakeholders identified key community assets such as parks and recreational centers, churches and faith-based facilities, restaurants and grocery stores, and transportation infrastructure. They also identified health-related community assets, such as medical and dental clinics and pharmacies, in addition to public safety services, such as fire stations. weTable participants also pinpointed several challenges in the community, such as flooded roads, sewage backups, flooded homes and vehicles, and the isolation of community assets due to lack of access during flooding situations.

An important element of the weTable application was its utility for surfacing and codifying collective local knowledge and for engaging residents in an understanding of the impacts of SLR and flooding. As part of the demonstration project, data was collected from participants about the usefulness of the weTable participatory mapping exercise in terms of (1) visualizing the problem of SLR; (2) highlighting community assets; (3) identifying any community challenges associated with SLR and flooding; and (4) understanding the severity of the problem of flooding and SLR.

Results of the participants’ evaluations are summarized in Figure 5.2, where the mean evaluation ratings for each aspect of weTable usefulness on a 5-point scale (1 represents ‘Not at all useful’; 2 represents ‘Slightly useful’; 3 represents ‘Somewhat useful’; 4 represents ‘Moderately useful’, and 5 represents 'Extremely useful') can be found. Overall, participants rated the weTable participatory mapping exercise between moderately and extremely useful. They gave the highest ratings to usefulness in terms of communicating SLR and encouraging social learning, specifically aspects like facilitating community-wide discussion, visualizing the problem, and understanding the severity of flooding and SLR. They gave slightly lower ratings for the knowledge co-production functions of highlighting community assets and identifying community challenges. These results are consistent with the research on participatory mapping that points to the process of mapping as more important than the resulting map since the former provides the mechanism for participants to interact while learning from each other and refining their knowledge about resilience. Results show that participatory mapping can, by directly engaging residents in jointly creating spatial data, be a process-driven and vital way of building knowledge and fostering learning and deliberation about a complex issue like SLR.

Figure 5.2: Participants' assessments of weTable usefulness (mean scores and variability of scores)



Note: Response scale 1-Not at all useful, 2-Slightly useful, 3-Somewhat useful, 4-Moderately useful, 5-Extremely useful

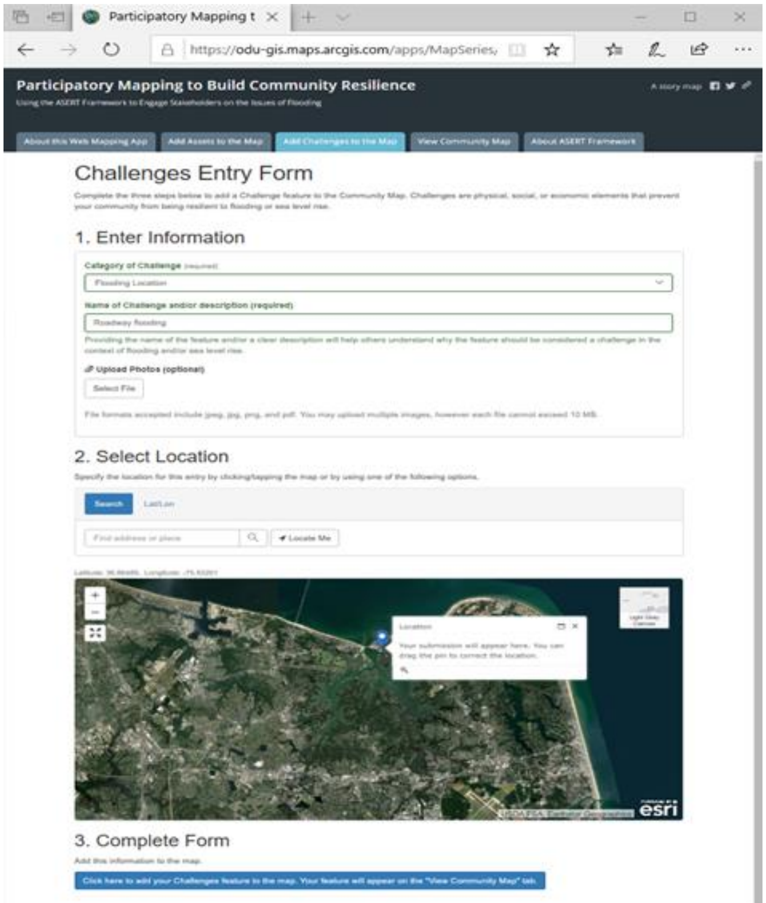
Source: Analysis by authors.

A web-based community mapping tool

The demonstration project, by design, had limited scope and reach. To engage more residents in co-producing spatial data about community assets and challenges or vulnerabilities to flooding, we subsequently created a web-based community mapping application, using an ArcGIS StoryMap, that could be deployed to a broader population of residents over a wider geographic area.[1] This web-based community map built on the weTable exercise and provided local residents with an opportunity to identify and offer input about assets and challenges in their community.

[1] The web-based community map is available here: http://bit.ly/resiliencemap

Figure 5.3: Web-based community map and the option to enter and identify a community challenge



Source: Map accessible at: https://odu-gis.maps.arcgis.com/apps/MapSeries/index.html?appid=b671f417edf146aba58210092aa06718

Using the web-based story map, local residents could identify an aspect of the community that is challenged by flooding and SLR. Figure 5.3 illustrates the community challenges component of the web-based community map, where residents can select a type of challenge (such as flooding location, infrastructure, business and economic, etc.), create a label to identify the challenge, and then specify it on the map. They also have the option of uploading photos associated with the community challenge.

Participatory mapping in community meetings

Participatory mapping exercises were also used in ASERT community meetings to support a locality's comprehensive SLR and recurrent flooding planning process. Specifically, the co-produced spatial information was used to validate the models and assumptions and to ensure that local knowledge and community concerns were considered in the planning process. In the ASERT community meetings, participatory mapping co-produced data on community assets and community challenges by taking two different approaches. The first approach used the weTable in a way that was similar to its use in the demonstration project, a method that allowed participants to identify community assets and challenges.

The second participatory mapping approach used at these community meetings involved identifying and locating travel disruptions due to flooding. Using a large-format laminated map of the city, participants were able to locate their neighborhoods and travel routes, and then they placed plastic sticky tabs with short descriptions of locations where they had experienced travel disruptions due to flooding or where flooding made streets, roads, highways, bridges, and intersections impassable, or passable with some degree of risk. Participants placed sticky tabs anywhere on the map where they had experienced flooding that did not allow them to reach their desired destination (see Figure 5.4). Unlike the weTable approach, which offers a low-cost, high-tech participatory mapping option, this second approach is both low-cost and low-tech, which allows it to be used both when resources are scarce and in communities that may have low technological literacy or that may have challenges using technology.

Figure 5.4: Participatory mapping exercises during community meetings

Source: Photos by K.A. Anuar

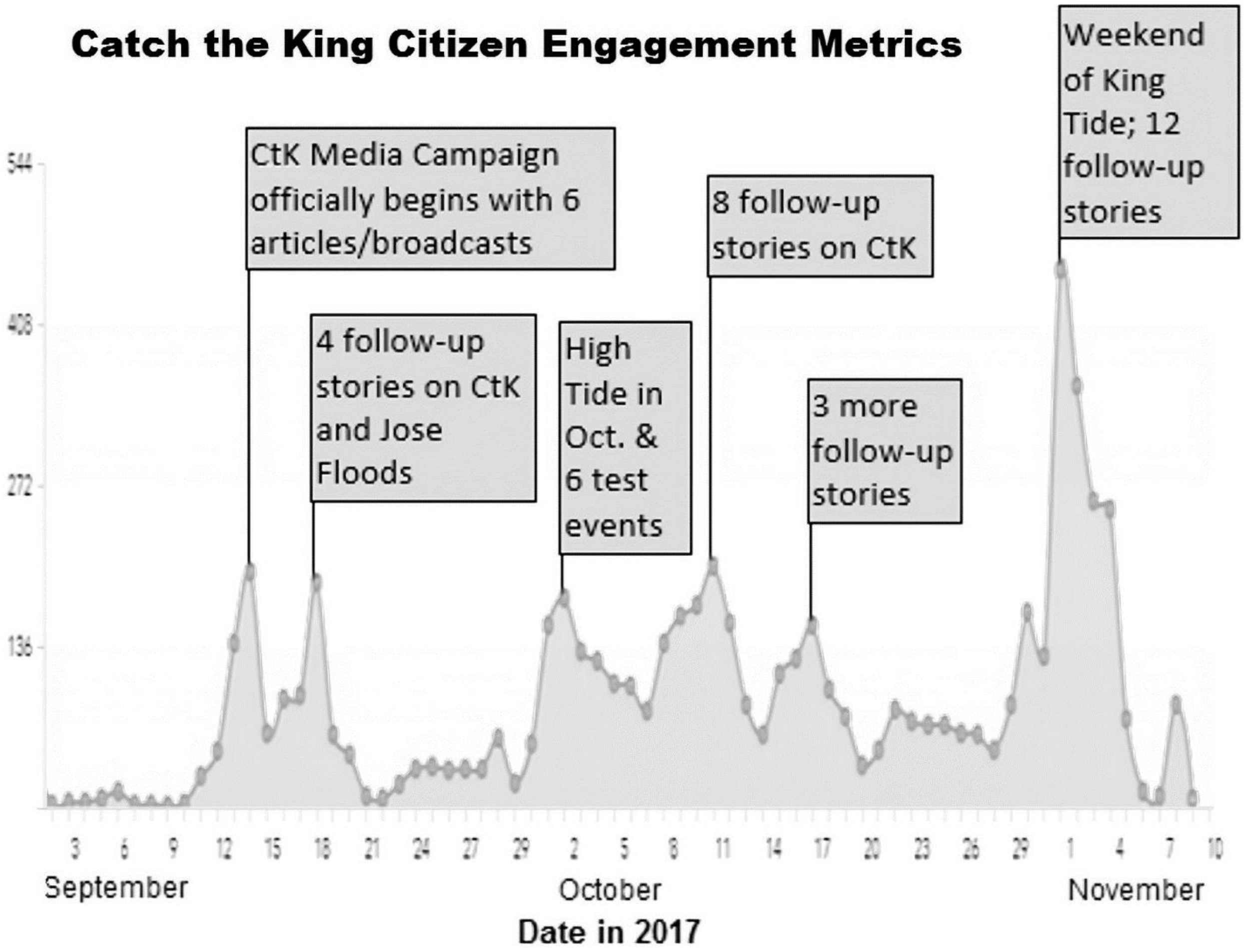
Catch the King - Citizen Science Inundation Mapping Initiative

Catch the King (CtK) is a crowdsourced GPS data collection effort that was formed as a community-supported technological mapping project founded by several Hampton Roads digital, television, and print media groups and by the Commonwealth Center for Recurrent Flooding Resiliency. The media project partners are WHRO Public Media, *The Virginian-Pilot*, *the Daily Press*, and WVEC News 13. These organizations were regularly writing stories on nuisance flooding, and the organizations felt compelled to address the issue in a more meaningful way than simply reporting on it. CtK uses a mobile-based flood mapping application that asks citizens to report inundation near them by uploading geotagged images and GPS flood extent data points that map the maximum extent of the tide’s reach.

CtK's goal is to recruit citizen-scientist volunteers to map the maximum inundation extents of king tides (and other more significant inundation events) and to validate and improve predictive models for future forecasting of increasingly pervasive nuisance flooding (Loftis, 2017). The CtK participatory mapping effort is the world's largest simultaneous citizen-science GPS flood data collection effort. In fact, in 2019, CtK was certified by Guinness World Records for having ”the most contributions to an environmental survey” on the planet (Guinness, 2019). CtK was effectively publicized and promoted by the local news media, garnering 722 citizen-scientists to map a single tidal flooding event on November 5, 2017, throughout the 18 cities and counties in the Hampton Roads region (Loftis, 2017). Citizen-scientists used the free SLR mobile app to report time-stamped GPS flood extent measurements and photographic evidence.

Figure 5.5 shows the citizen engagement with the CtK StoryMap (from September 1 to November 10, 2017). According to ArcGIS Online's data metrics, the invitation story map received 7,315 page views in less than 2.5 months, for an average of 105 page views per day during this period (see Figure 5.5). Ultimately, CtK, in 2017, its inaugural year, surveyed a total of 59,718 high watermarks and captured 1,582 photographs through the efforts of 722 citizen-scientists (Loftis, 2017; Guinness, 2019). CtK was repeated in 2018 and 2019 (Loftis and Katragadda, 2019).

Figure 5.5: Citizen engagement time series chart



Source: Analysis by authors based on data from the Story Map (accessible at:

http://arcg.is/1f8W1q

Since many CtK citizen-scientists were students or teachers working on school STEM projects, the early timing of this flooding in the Virginia academic school year coupled with the efforts of WHRO Public Media to integrate CtK lessons into the local school curriculum, significantly enhanced both the amount and the quality of the citizen-science data being collected. In 2018, 144 classrooms across the region participated in CtK, teaching related lessons in multiple subjects. Examples of lessons include:

(1) the *physics* of amplitude, frequency, and phase of tides and long waves,

(2) the *trigonometry* of waves, and

(3) the *environmental science* implications of sea level rise and climate change.

Mapping methods for coordination and data capture

Citizen scientist participants engage with CtK for a variety of reasons, mostly related to personal interests in aiding their flood-beleaguered communities. As SLR and tidal flooding increasingly impact coastal Virginia, CtK offers residents a chance to crowdsource vital information about the tides' reach. The coordination of CtK involves 25 to 42 annual training events that guide and instruct prospective citizen-scientists in the proper ways to collect meaningful validation data and photographs for flood monitoring efforts. The organizational structure for citizen-scientists follows a hierarchical scheme. At the top of the organizational chart, CtK is led by a citizen scientist coordinator who has served in that role since CtK's inception. Below this coordinator is over 65 to 120 "Tide Captains" who lead localized smaller groups of citizen-scientists. In most cases, these Tide Captains are knowledgeable school teachers, philanthropic organization leaders, and enthusiastic users of the Sea Level Rise mobile app who, in turn, train neighbors, friends, and family (Loftis et al., 2019).

Finally, at the bottom of the organizational structure are the citizen-scientist "Tide Mapper" participants, each of whom commits to attend a training event that informs them on how to collect data with the Sea Level Rise mobile app and what data is useful to collect. Then, during a CtK high tide event, these participants spend 30-60 minutes mapping flooding. Tide Mapper participants physically use their phone's GPS to map the inundation extents of flooding at their assigned locations, note floods or any other trouble spots, take photos to document what's occurring in their area, and then share that information with others. Using the Sea Level Rise mobile app, they capture three types of flood data useful for model validation:

(1) Breadcrumbed GPS locations for mapping high water contours during flooding

(2) Time-stamped, geo-tagged pictures including directional facing information, and

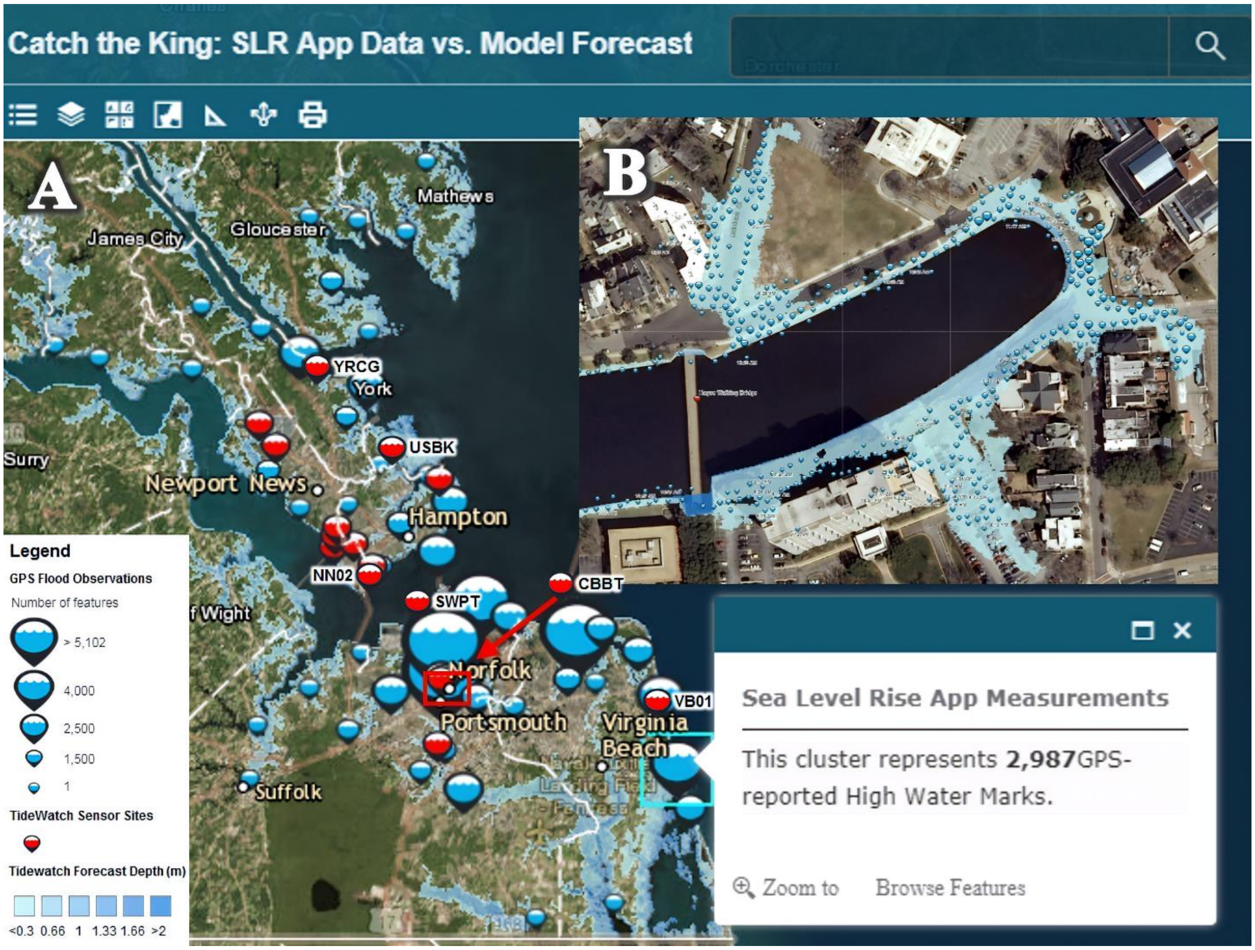
(3) Field observations and text notes that offer explanations of flood conditions.

Using crowd sourced data collected by citizen scientists

Time-stamped GPS data points and photographs were collected by citizen-scientists to effectively breadcrumb/trace the high-water line. Citizen-scientists pressed the Save Data button in the Sea Level Rise mobile app every few steps along the water's edge during the king tide's peak in each CtK event. Spatial data collected for each king tide event were aggregated through the Sea Level Rise mobile app and shared online using interactive web maps. This allowed citizen-scientists and interested parties with minimal digital mapping or GIS experience to visualize their GPS observations on the participatory mapping products alongside the flood model predictions produced by the Virginia Institute of Marine Science (VIMS).

The map, shown in Figure 5.6, is populated with publicly-accessible Sea Level Rise app data, local water-level sensor data and forecasts, and VIMS' Tidewatch Map predictions, providing CtK's participants and any interested parties with full access to the data. This kept VIMS accountable to its model's accuracy by publicly displaying its accurate flood predictions and where there were discrepancies due to overprediction or underprediction. The figure shows an overview of the region, featuring the 2017 king tide maximum inundation forecast from the VIMS' Tidewatch Model in blue, GPS citizen science observations as blue dots, and water level sensors from the Tidewatch Charts as red dots. The inset (labeled B) shows a high-density concentration of flood validation data in the historic Hague community of Norfolk where the model had a favorable agreement with the citizen science observations.

Figure 5.6: Comparison of responses collected by the free Sea Level Rise mobile application forecast from the Tidewatch Map



Source: Map accessible at: http://arcg.is/1HLOPS

This data interactivity spurred high engagement and participation for students involved in STEM research or related educational classes. Figure 5.6 shows an aggregated point map of 59,718 high water marks superimposed on the Tidewatch Maps throughout the greater Hampton Roads region and highlights the extent of areas not covered by automated sensors that were surveyed through CtK in 2017. The value of participatory mapping, in CtK's case study, is most evident in areas where there was a lack of automated sensor data, and in places like rural localities, where automated monitoring solutions would be too costly to maintain or would be otherwise impractical.

Implications for Practice

This chapter discussed how participatory mapping can be used (1) to make climate change communication more accessible through visualization of SLR and climate change risks, and (2) to co-produce spatial knowledge with stakeholders that informs models and projections and that can ensure community input into plans, policies, and practices. We conclude this chapter with some implications for practice and some key considerations for climate change communicators interested in participatory mapping approaches.

(1) Participatory mapping should be used as part of a broader engagement effort. In the two examples discussed in this chapter, participatory mapping was embedded within the ASERT framework and as the citizen-science component of CtK. In each example, participatory mapping was the tool used to solicit and codify local knowledge, with the specific goal of supporting the broader engagement effort.

(2) Participatory mapping is a means to an end, not an end itself. In the ASERT example, the co-produced knowledge that resulted from participatory mapping was used both to validate models and assumptions underpinning the locality's comprehensive SLR planning process and to ensure that local knowledge and community concerns would be considered in the planning process. In CtK, data from citizen scientists, collected through the participatory mapping process, was used to validate and improve predictive models

for forecasting of nuisance flooding. The data could also be used by citizen scientists themselves to conduct analyses of flooding.

(3) Successful participatory mapping revolves around the user experience. In this chapter's examples, this was achieved by ensuring that people with no knowledge of GIS, or with limited technological proficiency, could still interact with maps and could contribute to knowledge creation and communication regarding the complex issue of SLR and climate change. In the ASERT example, this involved using a large format map and sticky tabs to collect data during community meetings and using a simple data entry form that incorporated a web-based story map. CtK included numerous citizen-scientist training events to ensure that participants were comfortable with the Sea Level Rise app and with their data collection activities.

(4) Participatory mapping is flexible, and it can include approaches that range from low-cost and low-tech to high-cost and high-tech. The ASERT participatory mapping examples include approaches that were low-cost, low-tech, and low-cost, high-tech. The CtK example, on the other hand, because of its use of a proprietary phone app, illustrates a high-cost, high-tech approach. However, the high cost was justified, given the phone app led to the capturing of 60,000 high watermarks and 1,500 photographs, just in the first year. Scope or reach, technological literacy, accessibility, and cost are among the factors that should be considered in selecting the appropriate participatory mapping approach.

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