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Living Lab Program for Climate Change and Conservation

Project title:
Visualizing Climate Change Impacts in Coastal Protected Areas

Lead researchers

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Research findings

The objective of this research is to explore the use of realistic visualizations as tools for climate change adaptation planning, environmental management, and other activities related to protecting ecological, social, and cultural values in protected areas. The project used Mitlenatch Island as a case study, and the major research activities consisted of (1) developing the novel interactive visualization tool, and (2) testing it with focus groups to gain feedback and insight on its usefulness and potential applications. Research findings have been produced through both these activities, and they are discussed in further detail below.

Visualization development: The visualization tool was developed as a realistic virtual environment that can be navigated from the first-person perspective. Unlike other visualization research that approaches the development of these tools with distinct planning objectives and scenarios in mind (e.g., Salter et al., 2003; Schroth et al., 2011; Tress and Tress, 2003), this research took a more exploratory approach for investigating a range of potential capabilities and applications of these tools. To this end, the research team experimented with a variety of features and functions when developing the Mitlenatch Island visualization, and this development approach resulted in a number of valuable insights, including:

A tool for exploring multiple objectives: Due to the climate change focus of the Living Labs Program, some of the first functions implemented in the Mitlenatch Island visualization were those that allow users to examine effects of different sea level rise scenarios on the island park, these being scenarios defined by the Intergovernmental Panel on Climate Change's (IPCC) Representative Concentration Pathway (RCP) scenario set (IPCC, 2014). The tool demonstrated to be useful for this purpose, and it revealed that vegetated areas near the southern beach of Notch Meadow of Mitlenatch Island are potentially more vulnerable to sea level rise than those near the northern beach (Figure 1). However (and perhaps more importantly), the tool proved to be useful for exploring multiple objectives for park management in concert, using the same platform. For example, in this study (and based on BC Parks and stakeholder conversations), we also included the ability to visualize prescribed burning and native vegetation restoration in Notch Meadows, using the Mitlenatch Island Fire Restoration Plan (Maslovat et al., 2019) to guide the design of these scenarios.

Figure 1. *Sea level rise under the RCP8.5 scenario, depicted using the Mitlenatch Island visualization*

A platform for exploring maps and imagery: The visualization platform demonstrated to be quite versatile in terms of the functions that could be incorporated into the tool, and we explored a range of these functions. In this exploration, we found that the ability to examine maps and orthophotos to be one of the more straightforward and useful functions to implement: straightforward in the sense that (once this function has been built into the visualization) new maps can be added with ease and relatively little effort, and useful in the sense that it allows for park managers and stakeholders to see their own maps in an interactive, 3D environment. During the visualization development process, we incorporated multiple maps provided by managers/stakeholders, including the fire restoration plan maps (Maslovat et al., 2019) and orthophotos from 2017 and 1982. We are currently working on making this a user-side function, that allows users (and not just developers) to easily upload and explore maps on the platform.

A combination of abstract and realistic elements**:** The visualization tool was designed to be a realistic representation and experience of Mitlenatch Island; however, during its development, we found that there was opportunity and value in also adding abstract elements. For example, IPCC's (2014) RCP scenarios have uncertainty ranges for their projections of sea level rise, and we represented the high-range estimate using highly-visible, yellow-plane elements that can be toggled on and off. In addition to providing useful information on high-range estimates, these abstract elements also more clearly show where an inland migration of coastline will encroach on terrestrial habitat (Figure 2).

A potentially powerful tool for outreach and education: The Mitlenatch Island visualization tool could have important education and outreach application, in addition to being a planning and management tool. During the visualization development stage of this project, we had conversations with stakeholders and potential users that inspired us to include capabilities for playing videos at different locations and points-of-interest on and around Mitlenatch Island. Currently, the tool contains 'placeholders videos' (i.e., animations created by the Co-Lead Researcher for another project), and the points-of-interest were arbitrarily set; however, this function holds possibilities for presenting videos, footage, stories, etc. that share key information about the park and its ecological and cultural values.

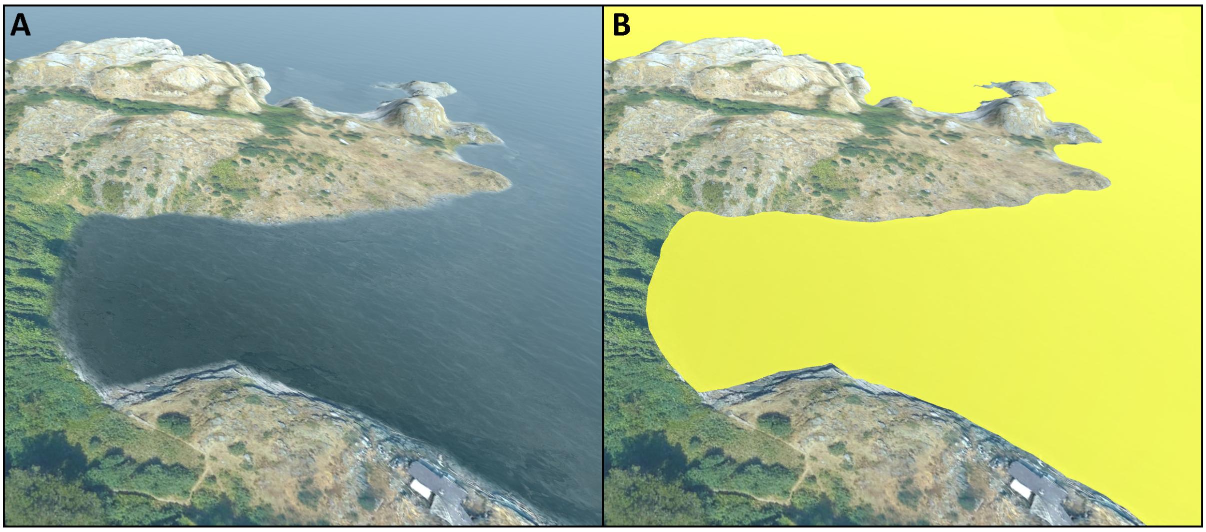

Figure 2. *Sea level rise projection shown (A) without uncertainty and (B) with high-range estimates*

The importance of field work and ground truthing: The vast majority of the visualization development work was done without setting foot on the island, involving the collection and integration of spatial data from multiple sources, stakeholders, and project partners. This on itself constitutes an important insight from the project, as it demonstrates that a virtual experience of a park can be developed without physically entering park and potentially impacting the ecosystem during fieldwork. However, we also found that there were limitations to developing the visualization purely through remote work, and thus we conducted a field trip to collect photographs, orthophotos, and LiDAR data, allowing us to 'ground truth' and confirm the nature of some of the elements within our visualization. These data allowed us to refine the visualization to make a more accurate representation and experience of Mitlenatch Island; for example, earlier versions of the tool displayed vegetation that is much denser than seen in the real environment, and based on our photographs, we revised the visualization accordingly.

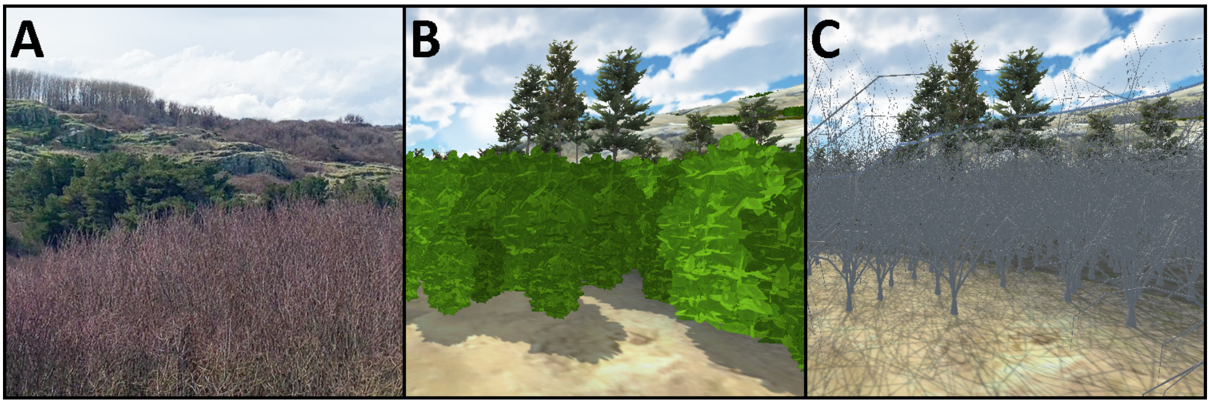

Figure 3. *Vegetation in (A) photograph, (B) first version of visualization, and (C) revised visualization*

Workshops: After completing a beta version of the visualization tool, we held workshops with members and affiliates of the Laich-Kwil-Tach Treaty Society (LKTS), BC Parks, the Mitlenatch Island Stewardship Team (MIST), and Terra Remote Sensing. The type of visualization tool created for this project (i.e., a realistic and navigable virtual environment) is novel in terms of serving as a tool for park planning and management; thus, the workshop feedback provided valuable insights on the potential of these tools and their applications. Key findings from the workshops include:

Incorporate temporal dimensions and highlight impacts: Workshop participants gave suggestions for building on the climate change features in the beta version of the tool to better highlight potential impacts. Some of the suggestions included showing how rising sea levels would change the coastline and result in erosion and inland migration of the intertidal zone. Other suggestions included added a temporal dimension to the visualization to show potential changes in the island's landscape and vegetation over time in response to a changing climate.

Use the tool for visitor experience and education: A number of the comments from workshop participants related to visitor experience and education, particularly in terms of directing park visitors to stay on the trails. Suggestions for the visualization included showing impacts to vegetation that could occur when visitors continually go off-trail, as well as incorporating data and visual elements that represent visitor traffic. The latter could be done by added human models to the visualization, as done in a previous visualization project conducted by the Co-Lead Researcher (Newell 2017a,b). Workshop participants also noted that the visualization could be used as a tool for allowing visitors to virtually experience park areas restricted to general public, while also clearly highlighting the paths that people need to remain on when visiting the island.

Identify and highlight conservation areas and species of interest: Workshop participants suggested that the visualization tool could support biodiversity objectives by highlighting conservation and nesting areas. Highlighting these areas would be useful for capturing and communicating specific locations of sensitive habitat to managers, stewardship volunteers, and (so they avoid and do not disturb these areas) the general public. Examples for Mitlenatch Island discussed in the workshops, include highlighting/visualizing rockfish conservation areas and gull nesting sites. In addition, suggestions were made to link the visualization tool with other useful tools and databases, such as providing links to the iNaturalist website (www.inaturalist.org) so that users can explore relevant local species data while navigating the visualization environment.

Use as a crowdsourcing tool: Workshop participants provided interesting suggestions around using the visualization as a crowdsourcing tool. It was suggested that people can use to tool specifically for reporting whale sightings, and due to the first-person perspective, the visualization offers, the tool could be used to report sightings from the same (but virtual) location and perspective that the whale spotters experienced in the real-world. Other crowdsourcing suggestions were made related to LiDAR data; as LiDAR scanner applications on smart phones become more sophisticated, visualization developers can take advantage of these technologies by working with communities and the public to collect 3D models and terrain data.

Develop a tool for integrating resource, social, and environmental considerations: The workshop discussions broadened beyond the Mitlenatch Island context, and we explored potential visualization applications for other places and environments. In these discussions, we spoke about ways these tools can be used to balance resource, social, and environmental objectives. The example of Quadra Island was discussed, and it was noted that the tool could be used to visualize forestry activity and potential impacts to the viewshed (as done in Lewis and Sheppard, 2006). Other suggestions included developing the visualization with analytical capabilities, such as a tool that would be able to calculate both the amount of wood harvested from different forestry scenarios, as well as the associated impacts to wildlife habitat. Inspired by these discussions, we are currently brainstorming and devising approaches for creating such a tool, and are hoping to develop a proof-of-concept that could lead to a greater research project.

Highlight and visualize cultural features and values: The workshop discussions illuminated possibilities for highlighting cultural sites, such as those that are important to local Indigenous communities and histories. A particularly interesting suggestion was presented, involving the use of oral history and archeological information to recreate Indigenous villages that were historically present in protected areas (and other areas). If done in collaboration with the appropriate communities, this type of visualization could provide a means of saliently communicating important information related culture, history, and traditional territories.

Develop a tool that can be experienced at multiple scales: In the workshops, we discussed the development of a visualization that captures and represents multiple scales, which is a challenge that has been articulated in other visualization work (e.g., Newell et al., 2021). Our workshop discussions explored questions around how these types of visualizations could be developed as tools for managing larger parks (i.e., parks larger than Mitlenatch Island) and networks of protected areas. This is a significant challenge because first-person, on-the-ground visualization experiences require developing virtual environments with high degrees of detail and resolution, that is, much higher than can be accomplished when modelling large areas. Ideas and approaches for addressing this challenge included creating a larger, coarser-resolution visualization, with capabilities for users to zoom in and 'land' on higher-resolution smaller parks/spaces, found within the greater area and park network.

Methods summary

The research methods involve three major activities: (1) visualization development, (2) fieldwork, and (3) workshops. Each of these activities are briefly described below.

Visualization development: The visualization development used methods developed by Newell et al. (2017a,b; 2021), involving a workflow from geographic information systems (GIS) to video game engine software (Figure 4). The process involves a combination of ArcGIS to maintain spatial accuracy, Adobe Photoshop to develop/format maps and realistic textures, Trimble SketchUp to development realistic 3D objects, and the Unity 3D video game engine to create a dynamic and navigable virtual environment. The development process is only briefly summarized here;0 for detailed information on how to develop these types of visualization tools, see Newell (2017a; 2021).

Figure 4. *Workflow for developing visualization, from ArcGIS to Unity 3D game engine*

The visualization consists of two terrain models: (1) a high-resolution terrain model of Mitlenatch Island, and (2) a low-resolution terrain model that captures the surrounding viewshed. These terrain models were built using (respectively) high-resolution LiDAR data obtained from Terra Remote Sensing and provincial Terrain Resource Information Management (TRIM) data. Once the terrain models were developed, orthophoto images and surface textures were added to create realistic terrain surfaces. Then, other elements were added in order to develop the virtual world and enhance its representation of the real-world environment, such as an ocean surface, 3D models of vegetation, a model of the volunteers' hut, light sources, atmosphere and sky imagery, and other elements. After developing a realistic virtual environment, features that enhanced the visualization's ability for serving as a park planning and/or education tool were added through scripts, such as functions for toggling different tide and sea level scenarios and for exploring different fire restoration maps and scenarios.

The beta version of the visualization tool contained multiple features intended for supporting park planning and management objectives. Such features included the ability to explore sea level rise scenarios, fire restoration planning scenarios, changes in landscape vegetation (as seen through orthophotos), and heights and densities of vegetation on the island. In addition, users can explore Mitlenatch Island scenarios and imagery through both a first-perspective and a map view (Figure 5). Furthermore, the visualization contains functions for visiting 'information sites' and playing videos related to these sites.

Figure 5. *Mitlenatch Island visualization in (A) first-person perspective mode, and (B) map view*

Fieldwork: As discussed above, much of the visualization work was done using previously collected data, without needing to physical access the island. However, some field data were collected to gather images of local vegetation and other island features in order to inform the modelling and appearance of different elements within visualization elements, as well as for examining changes in landscape and vegetation that could have occurred from when the last set of data were collected. The fieldwork was conducted in early March 2021, where we performed a drone flight from a location near the southern beach (Figure 6). Data collected by the drone included both LiDAR and orthophoto imagery. In addition, we collected photographs of vegetation and other objects in the park that were found near the drone launch site.

Figure 6. *Drone flight conducted on Mitlenatch Island for collecting LiDAR and orthophoto data*

Workshops: As noted above, the workshops held in this research project involved members and affiliates of LKTS, BC Parks, MIST, and Terra Remote Sensing, and we ran these workshops to explore the usefulness and potential applications of the Mitlenatch Island visualization tool. Two workshops were held by Zoom in mid-March, involving groups of 7 and 8 (including the researchers). Albeit small, these group sizes are comparable to those seen in other visualization research (e.g., Lewis and Sheppard, 2006), and such small sizes are effective for encouraging discussion and ideas from all participants, particularly when holding the workshops in online settings.

The workshops began with a round of introductions and then a presentation on the research and its objectives was given. As per the University of Victoria's ethics standards, a letter of information for participant consent was both provided and read to participants, which provided information on the research objectives, importance, procedures, participant inconveniences, benefits, risks, process for withdrawing, confidentiality, dissemination of results, and data management. Following the reading of the letter, a demonstration of the visualization tool was provided, and participants were given time to try out the tool on their own computers. Finally, a discussion on the visualization was held, and during the discussion, the researchers continued to demonstrate/operate the tool to stimulate ideas and suggestions. The discussion was loosely guided by the following questions:

- *What sort of insights did this visualization give you regarding Mitlenatch Island?*
- *What types of park planning strategies do you think this tool would be useful for? What other applications and uses do you think this tool could be useful for?*
- *What features do you like about this tool? What features could be improved?*
- *Do you have any thoughts about how the tool could be further developed?*

Key outcomes for BC Parks

Key outcomes from this project for BC Parks are three-fold:

Visualization tool: The beta version of the visualization tool is available for BC Parks to download, and it can be accessed from the web page: www.coraluvic.ca/sidneyspitviz/mitlenatch-island. We plan to continue developing the tool, and as we create new versions and upload them to the server, the most recent versions will be available from the same download links and web player. The project detailed in this report is the first phase of a multi-phased research effort, and we plan to incorporate comments from BC Parks workshop participants when developing future versions of the tool. In addition, future phases of the research will involve delivering training sessions to potential users of the visualization tool. BC Parks staff are welcome to join these sessions, and they will be provided with a working project of the visualization tool that can be further developed to include other features, maps, objects, and scenarios.

Dataset: The project resulted in preliminary high-resolution LiDAR and orthoimagery data collected from UAVs that capture current topographic and vegetation conditions on Mitlenatch Island. These preliminary data have been processed to create digital elevation models (DEM), orthophoto maps, and other representations of the island (Figure 7). During the data collection process, the research team identified multiple challenges and opportunities with collecting LiDAR and orthoimagery on Mitlenatch Island, specifically that multiple days of data collection are required to adequately capture all parts of the island, and that data collection should take place during a time of the year when vegetation has produced leaves. With this knowledge, the research team is planning a subsequent field work campaign in the summer of 2021 to collect a more comprehensive and higher accuracy data. The processed data will then be made available to BC Parks who can use these data for their GIS and spatial planning needs.

Figure 7. *Orthoimagery of Mitlenatch Island data collected via drone*

Workshop outcomes: The workshop outcomes discussed above provide insight on the concerns and objectives for protecting ecological and cultural values that held by communities and stakeholders with relationships to Mitlenatch Island. Such insights could be useful for BC Parks in their efforts toward inclusive, collaborative approaches to park management.

Relevance to BC Parks management

The main outcome from this work is the Mitlenatch Island visualization tool, and as aforementioned, BC Parks can download the beta version (and will be able to download future versions) from the project web page. Although BC Parks workshop participants have had an opportunity to test out the tool, we recommend downloading the tool again and giving thought to how/whether BC Parks could use the visualization to examine priority areas for conservation and management on Mitlenatch Island. BC Parks could also consider whether the tool would be useful for their education and outreach efforts, and if so, they could use the embed code or direct link on the project web page to (respectively) display or link to the visualization from the BC Parks website.

As detailed in this report, there were a number of suggestions for improving and further developing the tool, and some of these were provided from BC Parks staff. We plan to refined, update, and create other versions of the tools; thus, it would be worthwhile for BC Parks to review the feedback and suggestions detailed within this report to see if there are any features that would be particularly useful to their management needs. BC Parks is welcome to connect with the researchers about these suggestions and considerations. For example, future versions of the visualization tool could include one that highlights rockfish conservation areas, and this could be develop in collaboration with BC Parks, with BC Parks providing the maps of these conservation areas.

This report recommends that BC Parks considers participating in future phases of the project, in particular the training sessions that we plan to offer to visualization user communities and groups. These sessions will involve learning how to use and develop the visualization working projects, so that new features can be added and new versions of the tool can be created, without needing the assistance of the research team. BC Parks is encouraged to remain connected with the researchers to learn more about these upcoming opportunities.

Project's challenges/opportunities

A major challenge for research projects that aim to collaboratively develop tools for planning and engagement is that it is not feasible to incorporate all feedback and suggestions from participants when refining and creating new versions of the tools (Newell et al., 2021). Regardless, rather than constraining the imagination of the participants, it is worthwhile to 'cast a wide net' so to speak, and to collect many suggestions and ideas for further developing these tools. In the case of this research, the type of interactive visualization developed for this project is relatively novel in terms of being a tool for park planning and engagement, and every idea and suggestion provided through the workshops could serve as an interesting avenue for future visualization research, whether this be done in the next phases of this project or in other studies.

The tool was developed for multiple platforms, including desktop applications for Windows and MacOS and an online version was embedded in the project web page. Some challenges were experienced by workshop participants when attempting to downloading and/or accessing the visualization. Such challenges highlighted the importance of having multiple versions and methods of access, and also the value of providing clear instructions on how to download and open the visualization application.

During the workshops, we discussed how specifically the online version of the tool provided valuable opportunities for collaborative planning, engagement, and public education, particularly due to it being easy for users to access. With the online visualizations, community and stakeholder groups could host versions of the visualization on their respective websites. Some technical challenges were experienced when developing and playing with the online visualizations, such as browser compatibility and limitations in the number and complexity of 3D models. However, the feedback from the workshops indicated that online access is useful; thus, exploring ways of addressing these challenges would be worthwhile research pursuit.

As discussed in the workshops, the types of visualizations explored in this research could be useful tools for highlighting different cultural and ecological features of protected areas. However, in some cases, visualization developers and user communities and groups may want such features to be visible only to members of the user communities/groups. In cases where there are sensitive ecosystems and/or cultural and archeological sites, displaying these to the general public through the visualization may be problematic, as people may wish to visit these sites, potentially causing impact. Based these discussions, we spoke about methods for creating differentiated access in the visualization tools, where different versions will have certain features/elements disabled so that they can be displayed on public websites, and then, the complete versions of the tool (i.e., with all features available) can be hosted on password-protected sites.

Conclusions/next steps

The project detailed in this report represents the first phase of a multi-phased research effort, and future phases will build on this work. We will review the feedback provided in the workshops to determine what can be incorporated in the next versions of the visualization tool. The tool will be refined accordingly, and then, we will reach out to the community and stakeholder groups that participated in the March workshops (including those who previously participated and members of these communities/groups who are new to the project) to arrange another set of workshops. Such an approach will allow the visualization tool to be developed through an iterative process, with multiple stages of engagement and feedback.

In addition to future workshops, we plan to hold training sessions on the visualization working projects and ways of further developing the visualization tools. The training will be held (ideally) in the fall of 2021 over a three-day period, and we will follow-up with the participants of these sessions with interviews in early 2022. In the interviews, we plan to discuss whether participants (and their respective communities and groups) have been able to make use of the training and visualization tools, and if not, what barriers or challenges need to be address to better harness opportunities and utilize the tools. Our hope is that this final research phase will serve to better equip user groups with the knowledge and skills to effectively make use of the visualization tools, with the ultimate goal of closing the gap between research and practice.

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