Techniques in Repeat Photography:

Monitoring the Quadra Hill Wetland Restoration Project

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Abstract

Repeat photography is an important tool used in landscape monitoring for the purpose of documenting the change of a landscape over time; in the context of ecological restoration it can give qualitative and quantitative insight into the trajectory of a restoration project. To gather an accurate depiction of an area, the combination of ground based (i.e. oblique) and aerial (i.e. nadir) imagery should be collected (Tricker et al, 2023). Oblique repeat photography typically consists of two types, landscape photography and focal point photography. Landscape photography is used when there is no direct focal point (feature) in the image, but rather the entire landscape is the subject. In contrast, focal point photography centers on a specific subject expected to change over time (United States Department of Agriculture, n.d.). Aerial imagery is the classic format that is used for landcover classification methods in remote sensing techniques. Establishing proper baseline imagery is essential prior to commencing a restoration project. This study addresses that need by producing reference photographs for the upcoming Quadra Hill (QH) wetland restoration on Galiano Island, B.C., led by the Galiano Conservancy Association (GCA). Prior to this project, the QH restoration site lacked detailed and repeatable photographic coverage; without reference imagery (i.e. historical photography) repeat photography is by definition impossible. Understanding and documenting historical data to promote success in restoration is discussed, and our work will create conditions for the long-term understanding of the landscape change. The methods focused on photo point, photosphere, and drone imagery to increase the photographic coverage of the proposed QH wetland restoration site. For photo point reference photography, both focal point and landscape techniques were researched and produced using a Fujifilm X-T4 digital camera with a 14 mm prime lens, generating .RAW files for the

highest quality images. The photosphere imagery captured a 360 degree image on an Insta360 camera, which in turn was placed into the ArcGIS Storymap platform that allows for interaction with 360 degree images. The drone footage collected nadir imagery using a DJI Mavic 3 Classic drone to display a large-scale aerial image of the entire landscape. All photography conducted was precisely documented in the ArcGIS Quick Capture app to ensure exact repeatability in the future to track ecological changes and the trajectory of the site. The process of establishing the reference photographs was captured and inputted into an ArcGIS Storymap, with the intention of furthering community and stakeholder engagement in the GCA, but more specifically in the QH wetland restoration project.

Introduction

The Galiano Conservancy Association (GCA) has proposed a wetland restoration project on their recently acquired (46.77 ha) Quadra Hill (QH) property, which will impact the adjacent property, (18.12 ha) Great Beaver Swamp (Huggins & Thompson, 2023; Galiano Conservancy, n.d.); however, there are insufficient visual data representing a reference (sometimes called baseline) point. Once these reference images are collected, the process of repeat photography can commence. Repeat photography is the technique of systematically photographing a landscape or focal point (i.e. a specific subject) in a way which can be repeated in the future to document changes in the area. In the absence of pre-existing historical photographs, precise repetition requires the establishment of detailed reference photographs, which is the primary focus of this study. The documentation of coordinates, azimuth, lens height and area description allow for a returning photographer to replicate the images (Karpilo, 2021; Lehman, 2021). The use of landmarks, such as a large tree, in photographs ensures easy repeatability. A reference photograph must encompass all these aspects, in areas both of direct interest and where unexpected change may occur. The photographic coverage of the study area was minimal prior to this project, with only two reference images available.

In this study, we aimed to remedy this issue using photo point, photosphere, and drone imagery. The photo point imagery consisted of groups of oblique photographs collected using both a landscape method and focal point method (Appendix 1). In landscape photography the entire viewshed is the subject, whereas focal point (or feature) photography has a specific, centered subject that is expected to change throughout time (United States Department of Agriculture, n.d.). The reference photography would also provide sufficient coverage in formats such as 360 degree photosphere imagery, with interpretive aspects imported into an ArcGIS Storymap, furthering the interpretive outcomes of this project. Additionally, drone imagery was captured, giving a photographic overview of the entire landscape in a single image, which can be used to assess land cover change. This visual coverage of the restoration site should provide context to the community and stakeholders to allow for further engagement in the QH restoration project, while allowing the GCA to track landscape trajectories.

The History of Repeat Photography

As the process of repeat photography consists of replicating aspects of pre-existing photographs, this technique is relatively new. Original systematic landscape photographs date back to the mid-nineteenth century, with the pioneering of the historic repeat photography technique often being accredited to Sebastian Finsterwalder in 1888 (Wright, 2022). This technique was primarily used in the disciplines of ecology and glaciology; Finsterwalder used his techniques to track glacial change in the Alps, which was later adopted by Sierra Nevada in the Canadian Rockies, among others (Wright, 2022). This technique was used primarily in small scale glacial and ecological monitoring projects, but was not popularized until the 1950's where it found a footing in mountain research monitoring (Wright, 2022). Throughout time, this technique has become widely adopted in landscape monitoring and research, as the imagery is easily interpretable and holds important high resolution ecological information about the study area.

Repeat photography has been used in National Parks of the United States for decades, such as in Denali National Park, where a project began in 1925 to document the mountain landscapes in Alaska (National Park Service, 2016; 2024). The focus of this project was to track glacial retreat, vegetation succession, and anthropogenic encroachment in a cost effective and easily interpretable manner (National Park Service, 2016; 2024). At the University of Victoria, Dr. Eric Higgs and colleagues have used repeat photography in the mountain ranges of western Canada through the Mountain Legacy Project (MLP) (Mountain Legacy Project, 2024). The MLP holds the world's largest systematic high resolution collection of historic mountain images, of which they are working to duplicate to explore the evolution of these landscapes (Mountain Legacy Project, 2024). These reference images were originally taken as a method of photographic surveying, and archived nearly complete coverage of the Rocky Mountains (Mountain Legacy Project, 2024). In the present day, these images serve as an unprecedented knowledge bank that can be used for analyzing the changes in these complex systems during a time of rapid climate change.

Repeat Photography Applications

Repeat photography is an important tool used to assess landscape change over time. The imagery can be used to perform land cover change analysis, track shifts in geological formations, and collect data that is interpretable to those without formal education on these subjects. Photographs can be taken at different temporal scales to track changing conditions, such as photographing different seasons to track vegetation responses to varying weather conditions. At longer scales, the development of a landscape through years, decades, or even centuries can be tracked. As well, these visual data give context to the landscape, and can hold more information than written descriptions. Images will include everything present in the field of view, and may include subjects that are discovered to be important.

In this study, reference photographs were produced to provide a baseline for future repeat photography projects at the GCA. In this study, prior knowledge of a planned restoration project on the QH property makes these images invaluable for demonstrating the project's historical development. With a lack of reference imagery present for the area, this study will provide necessary context to the work that the GCA will perform to transform a portion of the QH site into a wetland, and the succession of the wetland over time.

Study Area

The Quadra Hill (QH) and Great Beaver Swamp (GBS) sites are the location where this repeat photography study will be conducted. They are located at the center of Galiano Island, B.C. (Figure 1), within the shared, asserted, unceded and traditional territories of the Hul'qumi'num-speaking First Nations Peoples and those who hold traditional rights, responsibilities, and Indigenous rights and title in and around what is now known as Galiano Island (Huggins & Thompson, 2023). The QH property is present within the mid-island protected area network, which is a network of land owned by the GCA that spans from the north edge of Galiano Island to the south edge. This creates a corridor of protected area where restoration can take place, and biotic features can naturally transfer. QH is a part of a watershed that drains into the GBS using a retired logging road; therefore, work that is conducted on the QH property will directly impact the hydrology of adjacent properties, such as the GBS.

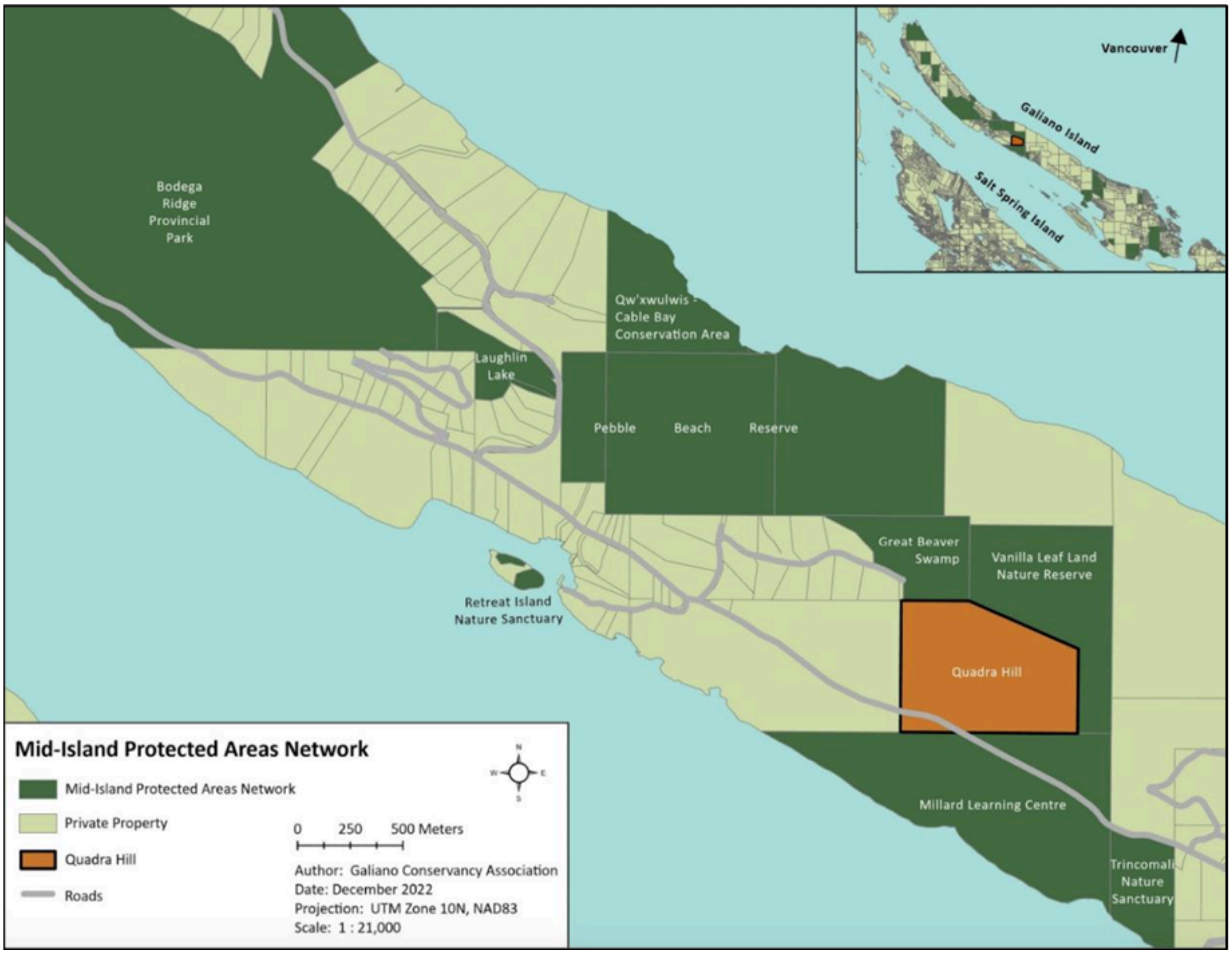

Figure 1: *Map of Quadra Hill property relative to nearby protected areas, spanning the middle portion of Galiano Island, BC. The map was created by the GCA, and retrieved from Thompson & Huggins, 2023.*

The QH site has a large mixture of land cover; for the purpose of this study, only the northwest portion of QH will be examined, as this is where restoration efforts will take place (Figure 2). These cover types were mapped with a layer of the ecological zones to determine the layout of the site (Figure 2). These ecological zones vary in moisture and nutrients; the QH site is composed of the Coastal Douglas-fir Biogeoclimatic zone (Ministry of Forests, Lands and Natural Resources Operations British Columbia, 2016). The layer of the ecological zones was placed as a basemap for the photosphere and photo point imagery locations (Figure 3), and was used to ensure effective photographic coverage of each zone.

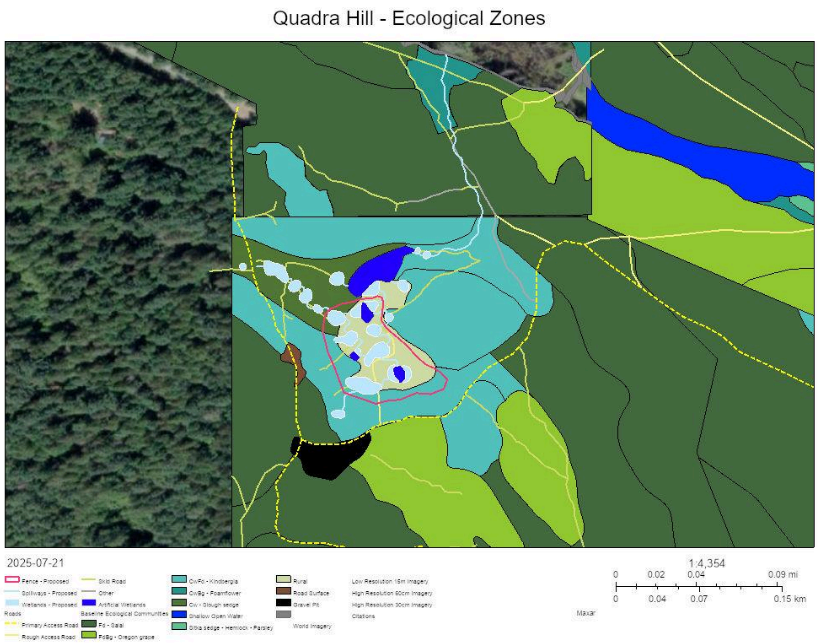

Figure 2. *Map of the ecological zones of the northwest portion of Quadra Hill and southern portion of Great Beaver Swamp, Galiano Island, BC. This map was created in ArcGIS by the Galiano Conservancy Association, and published 2025-07-21.*

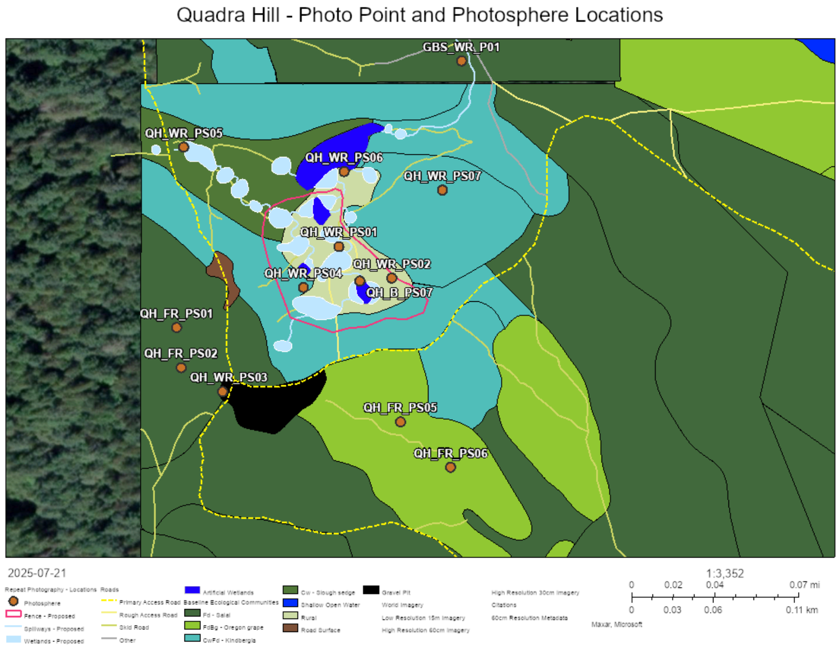

Figure 3. *Map of the ecological zones of the northwest portion of Quadra Hill and southern portion of Great Beaver Swamp, Galiano Island, BC.. Also depicted the point at which each photo point and photosphere image was taken (orange dots). This map was created in ArcGIS by the Galiano Conservancy Association, and published 2025-07-21.*

The QH site has a long history of human inhabitance, including logging, agriculture, and infrastructure construction (Huggins & Thompson, 2023). The dominant forest stand within the study area is Douglas fir, with sections of exposed grassy and weed pasture. The previous land use for the wetland restoration portion of QH was agricultural, with broken fence posts, wires, and feeding pastures evident (Figure 4). Other human structures such as small shacks and worktables were scattered throughout the site, intermingled with trash and abandoned personal items such as a bicycle. Few human-made dugout ponds were present in the pasture areas, which were an indicator for drainage system tampering throughout the property (Figure 5). These features result from many years of local, small-scale food production on the site. Now that this form of land use is no longer present, the GCA is planning to restore the site to a forested wetland ecosystem. The use of heavy machinery in this process is expected to cause a one-time disturbance to an already degraded site; therefore, these areas where the most change will occur are the ideal areas for photographic coverage.

Figure 4: *An old pasture on the QH wetland restoration site, with fence posts and boards constructed from material found around the site. These fence posts are soon to be destroyed. Image credit: Hannah Friesen.*

Figure 5: *A man-made pond present on the QH wetland restoration site, indicating a change to natural drainage patterns. Old fence posts are also present in the image. Image credit: Hannah Friesen.*

The GBS functions as the primary drainage basin of the QH restoration site. An old access road runs downslope from QH to the GBS, and diverts the drainage water from QH, which has in turn channeled the water instead of dispersing it throughout the area. This channeling of water has altered the ecosystems present, as there has been a disruption to the natural movement of water. Therefore, it has been proposed that the access road be removed, and the GBS be remodeled.

Methods

To determine the ideal location for reference photography of the QH wetland, an analysis of the previous reference images was necessary. Although three image sets had been taken, they did not capture the full extent of the wetland restoration site. Using the GCA ArcGIS web map (Figure 3), it was determined where imagery had been taken, and general areas where there was a lack of photographic coverage. To collect and maintain the systematic formats of the reference imagery at the GCA, the photo point and photosphere standards remained consistent with previous work. No drone procedure was outlined, and no aerial imagery of the wetland had been taken. Locations of potential photographic vantage points were recorded using the digital web maps, and a site tour was led by the GCA Restoration Coordinator Adam Huggins. During this site tour, six imagery locations were noted on July 10, 2025. Areas within five meters of large native trees were ideal, as these portions of the landscape would be left unaltered. As well, choosing vantage points located high above the landscape was preferred so a large portion of the site could be seen in a single image. On July 11, 2025, a second site visit occurred to revisit the noted vantage points, and photographs were taken.

The repeatability of the photographs, either photo point or photosphere, relies on the precise documentation of the process which was performed. At each photo site previously determined, rebar stakes were hammered into the ground as a physical marker for the photograph location. Flagging tape was labelled with image identifying codes, and tied to the stake. For the photo point process, after positioning the physical marker, a tripod was placed, centered, and levelled over the stake (Figure 6). This ensured that future repetitions of the image will be taken from the same precise location. In areas where a focal point existed, such as the old GBS logging road, the focal point technique was used. However, in areas where the whole landscape was proposed to undergo significant change, it was difficult to determine one focal point, thus, the landscape technique was used. To take the photo point imagery, a Fujifilm X-T4 digital camera with a 14 mm prime lens was used, allowing for 26.1 mega pixel resolution when exported as a .RAW file (Fujifilm, n.d.). The azimuth and lens height of the camera were measured, and these data were inputted into the ArcGIS Quick Capture app to ease repeatability; all images were taken at a 0 degree angle. If multiple iterations of a photo point were taken at differing angles, the tripod was adjusted, re-levelled, and a new azimuth was recorded. Manual camera focus was used to establish a proper focal point. To ensure thorough imagery, multiple photographs were taken with the field of view overlapping approximately 30%; these images may later be combined to create a panoramic view of the landscape.

Figure 6: *Photo point image being taken. Rebar stake with pink flagging tape is visible along the bottom center of the image. Image credit: Hannah Friesen.*

In the photosphere process, the same rebar stake was used as the photo marker. The Insta360 camera unfolded into a long stick with a camera at the top, which was then strapped to the rebar stake (Figure 7). The lens height for each photosphere was recorded in the ArcGIS Quick Capture app, and paper with photosphere codes were placed in each image to ensure images were accurately identified. There were no manual settings for the Insta360 photosphere camera; therefore, the photographs were captured automatically at 72 mega pixels and exported as a .JPG, a compressed image type that facilitates simple sharing with the public and is suitable for upload to ArcGIS Online (Appendix 2) (Insta360, n.d.).

Figure 7: *Insta360 camera being strapped to a rebar stake. In this image the camera has yet to be unfolded into its full height. Image credit: Chelsea Deren.*

To achieve a complete view of the QH wetland restoration site, a nadir image taken from high altitude was required. To achieve this, the use of drone imagery was employed (Appendix 3). We used a research grade DJI Mavic 3 Classic drone owned and operated by Dr. Eric Higgs. This drone is designed to take high quality orthographic imagery, at 20 megapixel still imagery and sub 0.5m locational accuracy (DJI, n.d.). To take the nadir imagery of the QH site, the drone was launched from the portable take-off pad in a grass clearing with few trees and shrubs. The drone was launched to 120m above ground level; the location of the drone launch was approximately 100m above sea level, therefore the imagery was taken at approximately 220m above sea level (Huggins & Thompson, 2023). Multiple images were taken with the drone to ensure full coverage of the study area. Metadata embedded within the image files provided geographic coordinates, allowing the imagery to be accurately replicable (DJI, n.d.). The drone used the photograph format .JPG (DJI, n.d.).

Once the data collection was complete, the imagery and geographic information was uploaded to the GCA server. To do this, the information inputted into the Quick Capture app had to be uploaded to the GCA ArcGIS Online web map. This was possible because the Quick Capture app was linked to the GCA base map. The GCA set up domains within the app to be filled out so that the data were properly formatted and geographic accuracy was ensured (ESRI, n.d.-a). The app was filled out as the photos were being taken, and when images were uploaded to the server they were given corresponding tags with the Quick Capture data. In regards to the tags, the GCA photo tag format was used; the tags consisted of the format:

Site_Project_PhotoFormatPhotoNumber. Image sets (photo points with more than one image) were consequently labelled with a letter after the code; for example an A at the end of the photograph code would indicate that it is the first photograph of an overlapping image set. An example of a photo tag from the current project would be *QH_WR_P05A*; all photos taken with their photo tags can be found in Appendix 1. The photography from both the drone and the photosphere camera were imported in .JPG image format, and the photo point imagery were uploaded to the GCA server in .RAW image format.

To ensure these data were easily accessible to the general public and the local community on Galiano Island, the imagery collected was imported into an ArcGIS Storymap. A Storymap is a web based application that is used to share data, such as interactive maps and imagery, in an easily interpretable and story-driven way (ESRI, n.d.-a). Once the imagery was imported into the GCA server, it was uploaded to an ArcGIS Storymap with the purpose of sharing with the Galiano Island community. A Storymap format was chosen since it is able to utilize the .JPG imagery along with the photosphere imagery in a proper format, displaying the interactive 360 degree image. The Storymap application was unable to carry file sizes larger than 10MB, therefore the .RAW image files from the Fuji X-T4 camera had to first be converted to .JPG images before uploading; the Apple Finder app file converter was used to convert the .RAW image type to .JPG, while also keeping a copy of the original .RAW image file.

Results

Photo Point, Photosphere, and Drone

The photo point results contain six locations, five of which are on the QH property, and one on the GBS property. Between these six locations, a total of 23 reference images were taken, with results present in Appendix 1. Six photosphere images were captured at varying levels of ecological integrity across the site, with images available in Appendix 2; however, these file types are best viewed in the ArcGIS Storymap produced in this study. A site description (Table 1) paired with the image code best represents the ecosystem coverage for each photo point set and photosphere. Eight drone images were produced, showing imagery of both the wetland restoration site and top down images of large mature trees. These drone images can be viewed in Appendix 3.

Photo Point/Photosphere Image Code	Site Description
QH_WR_P03 (A, B)/PS03	Vantage point from the road entrance to the QH site. Pile of course woody debris and gravel road prominent.
QH_WR_P04 (A-D)/PS04	On the treeline of the pasture, looking into the pasture. Grasses dominate, with few wetland species apparent. Large western redcedar tree used as a landmark.
QH_WR_P05 (A-D)/PS05	On the edge of the access road into the QH site. Overlooking an area where succession of wetland ponds will occur.
QH_WR_P06 (A-E)/PS06	Vantage point located on the border of an already existing wetland and the pasture. A prominent border is visually apparent between the ecosystem types. A fallen tree and piled soil creates a barricade between the difference in moisture.
QH_WR_P07 (A-E)/PS07	On a slight mound between two old growth trees. Viewing down the mound to the pasture from a different angle than previously.
GBS_WR_P01 (A-C)/PS01	On a slight hill looking down on the old access road of the GBS site. Heavily forested, rocky outcrops, and temperate vegetation dominates this ecosystem.

Table 1. *Each photo point and photosphere location (QH: Quadra Hill; GBS: Great Beaver Swamp), project (WR: wetland restoration), and point number with associated letter code for sequential 30% layered photographs (for photo point only). A site description of each point location is included. For visual reference, Appendix 1 contains all photo point images and Appendix 2 contains all photosphere images.*

ArcGIS Storymap

To demonstrate the impacts of the QH wetland restoration project, an ArcGIS Storymap was created including all the photo point, photosphere, and drone imagery taken through the duration of this study. The Storymap begins with a brief introduction to repeat photography and the QH wetland site, with a history of the land and what ecological zones are present throughout. The Storymap then leads into the 360 degree images taken, including their image tags. Next, the photo point imagery is available, where the images are collected based on the location that they were taken. Finally, the drone imagery is presented with details on how the footage was taken and its importance. After the imagery, the Storymap concludes by stating how repeat photography in restoration can lead to further community engagement. The Storymap is used as a summary of this paper, and can be accessed at:

https://arcg.is/1yePWb

Discussion

History and Site Trajectories

Repeat photography is a vital tool that can be used to understand both the history and trajectory of the QH wetland restoration site. Knowledge of the historic land use on the QH site will give further insight to how the ecosystem will react once restoration efforts commence. For example, the knowledge of past logging on other QH sites has furthered the comprehension of the current forest stand and class of the site, and what work is needed to place the ecosystem on a healthy trajectory. In terms of the wetland restoration, knowledge of past agricultural use informs the GCA of potential soil compaction and it can be inferred that hydrology of the site was likely impacted. When completing the restoration project, these root issues must be addressed before commencing work. Photographic documentation of this land use will assist the GCA in interpreting future conditions of the restoration site and understanding why certain areas respond as they do. As the GCA continues to grow, new staff will enter, who may not have reference to the history of the QH site, and having imagery of the site alongside written documentation will allow for a holistic view of the site's prior conditions. Recognizing the historical context of a site is essential in restoration projects, and photographic documentation provides a strong knowledge base. In this study of repeat photography, it was ensured that the history of the land would be documented, providing a baseline for comparison and increasing motivations for future restoration.

Analysis of Photo Point Imagery

Oblique imagery, such as the photo points taken in this study, are an easily interpretable form of landscape documentation. This type of imagery is taken at an angle similar to that of the human viewpoint, and is interpretable by those that are not familiar with orthographic photography or map reading (Wright, 2022). This makes the imagery presented by the GCA friendly to community members who may not fully understand the restoration process when looking at a land cover change map. The angle of this imagery, in the case of the QH 0 degrees, allowed for change in topography and relief to be documented in a way that would not be possible with nadir imagery. This will be particularly important in areas such as images QH_WR_P03A and QH_WR_P03B (Appendix 1), where a pile of large woody debris is proposed to be replaced with a mound of soil with a shallow relief; the 0 degree angle will appropriately demonstrate the change in elevation. Oblique imagery is also useful when image pairs are displayed neatly, side by side. The images are able to tell the story of the landscape and how it has evolved without the need for extensive writing (Wright, 2022).

Photo point imagery is a useful tool in many ways, but will only capture what is within the field of view. When imagery is taken, it is able to provide context to height and object relationality, but they often leave a lack of coverage behind large objects. When there is a large object in an image, it is not possible to know what is in its shadow. This can be solved by taking images of a landscape from multiple angles, and pairing them to create a full view of the landscape. In this study, it was attempted to capture all angles of the QH restoration site, although there are likely areas, such as in the shadow of large mature trees, that were not captured. Furthermore, photopoint imagery has a subject, whether it is a specific focal point or entire landscape. The photographs are used to take imagery of an area of interest, and therefore only portions of the landscape are captured. This means that some areas may not be captured due to lack of interest at the time of imaging, where important change may be occurring; this can be remedied by taking imagery of a full 360 degrees, although this is time consuming and costly.

Analysis of Photosphere Imagery

The 360 degree photosphere images document the general landscape, including areas which may not be visible in photo point imagery, such as tree canopy directly above the image site. The absence of a defined focal point allows these images to capture details that may appear insignificant at the time of photography but could prove important for future study; this proves their lack of focal point irrelevant, as they are used to give a general overview of the site. The 360 degree images are also an important interpretive tool to visually represent a landscape, and will engage those who may not be knowledgeable about restoration. Their interactive interface will draw visitors in, allowing them to immerse themselves in the past site to understand its trajectory. This is particularly valuable when a scannable QR code is available at the site, as it enables users to access past photosphere imagery on their mobile device and compare the current view with the historical record from that exact location; this is a successful method that the GCA has used with other restoration sites.

A drawback of using photosphere imagery is when taking photographs, the Insta360 camera warps the imagery. This causes many portions of the image to appear larger or smaller than their true size, similar to a fish eye lens. As well, the Insta360 camera works by using two lenses on either side of the camera to capture two images, then stitch them together (Insta360, n.d.). This means that along the seam of the images, there will be distortion, which are drastic in some cases. When the imagery is exported and viewed as a plain .JPG format, the image is warped and analysis is not possible until it is placed into a program, such as an ArcGIS Storymap, that will show the image in proper format (Appendix 2). These issues make it difficult to perform meaningful analysis on the imagery.

Analysis of Drone Imagery

Nadir drone imagery is valuable for conducting land cover analysis and is the standard format utilized in land classification, although it is not readily interpretable by the human eye (Tricker et al, 2023). There are an array of remote sensing software packages available to conduct land cover analysis in this format, such as ArcGIS Pro, Catalyst, and others. A nadir facing image is able to capture an entire landscape in a single image without any shadows, such as those that arise from oblique imagery. Drones are also able to capture imagery with excellent geometry, which can be used to perform distance calculations (ESRI, n.d.-b). This imagery may also be used as a basemap due to its geometric properties, which will be helpful to the GCA for planning. Generally, the nadir imagery collected is most useful to the GCA to perform further analysis.

Nadir imagery may present challenges for public interpretation, as viewers may have difficulties establishing orientation within the image. Top-down imagery is typically difficult to interpret to those with a lack of map reading skills (Wright, 2022). As well, the imagery does not give context to the topography of the landscape, and how this may change over time. This is why it is an important tool to use in conjunction with other repeat photography methods.

Challenges and Limitations

Selecting appropriate vantage points for reference photography provided a challenge to this project. To ensure sufficient coverage of the site, a specificity of photograph location was needed. With the proposed restoration project including the disturbance of heavy machinery across the site, vantage points needed to avoid areas that would be torn up or destroyed. This specificity led to a limited number of vantage points, some with less ideal coverage or lighting. Areas at high elevations were ideal, although the landscape of the wetland site was generally flat, meaning the field of view of the images was small. Large trees and tall weeds also proposed difficulty in selecting imagery locations, as they cast shadow on portions of the landscape. Furthermore, ideal photographic conditions were hard to meet within the time restraints due to field course length. When taking imagery, ideal conditions consist of overcast weather with little fluctuation in lighting (Lehman, 2021); these conditions were not able to be met, as it was sunny on the field work days that were allotted. This led to some images appearing washed out with intense lighting fluctuations between portions of the imagery (Appendix 1).

The source of photographic equipment must be discussed to ensure transparency in regard to repeatability of the reference imagery collected. At the time of this study, the GCA does not own a camera capable of repeating the high resolution imagery which was achieved in this study. Therefore, any repetition of these photographs using the GCA's technology would result in a lower resolution product. As well, the nadir imagery is not replicable at the time of this study as the drone equipment is owned by Dr. Eric Higgs. As a land trust and environmental charity, the GCA may not have funding to invest in expensive photography equipment; for the purpose of this study, we aimed to achieve the highest resolution reference imagery, and therefore used the personal equipment of Dr. Eric Higgs.

Conclusion

Community Engagement

Community engagement in restoration efforts contributes to the success of a restoration project (Keenleyside et al, 2012). In this study, there is an educational aspect to community engagement, in which we offer a platform for community members to learn about the history of the QH wetland from a pre-restoration reference point. This education is done through visualization (photographs), as well as the designed Storymap. This study provides education of the documentation and general awareness of restoration projects, which aids in the future success and engagement with the QH wetland restoration project (Keenleyside et al, 2012). Through this study, we aim to maintain transparency about the ecological foundation of the QH site prior to restoration efforts. This transparency will further the value which the community and stakeholders will hold for the future wetland and its trajectory. Building trust through this transparency aids with the success of the restoration efforts (Keenleyside et al, 2012). As well, by increasing community engagement, we aim to increase a sense of place and to facilitate long term land stewardship in the QH site. Involving community members in the restoration projects from the beginning of the project allows for a deeper connection to the land as it undergoes restoration efforts.

The creation of an ArcGIS Storymap was intended for community and stakeholder engagement in the QH wetland restoration project. The Storymap is a tool which, in the case of this study, will assist with the publication and sharing of the repeat photography process. Ultimately, this provides members of the community with a way to visualize the baseline of the

Quadra Hill site. By using the Storymap feature, we aimed to engage and educate people about the importance of understanding the history of an area and documenting it as a way to reflect in the future. It is hoped that this Storymap will be updated to add future repeat imagery of the site, or have a sister Storymap that will depict the changes that will have occurred. Having community engagement through the Storymap, will hopefully inspire future engagement and funding in restoration projects at the GCA.

Future Additions

This study has looked at the creation of reference photography for the GCA QH wetland restoration site, with the purpose of recreating this imagery in the future, using repeat photography methods. It is hoped that repeat imagery of the QH site will occur throughout the stages of restoration, and important information can be gained by looking at the paired images. The accurate and precise documentation of the process will allow the GCA staff and future ES 471 students to repeat the imagery with ease. The data collected from this repeat photography will document how the landscape will react to restoration efforts and evolve through time. This repeat documentation may occur on a variety of temporal scales to track different processes, such as annually to track general landscape change. This may include how vegetation grows throughout the year. This documentation will also be important if the land use of the plot changes through time (i.e. no longer a wetland). Photographs may also be taken multiple times within a year to track how vegetation reacts through different seasons and weather conditions. This documentation may be of interest in the wetland restoration in particular, as water levels in the area will rise and fall with seasonal variability in rainfall.

The data from this project may be used for assessing the landcover change through a variety of methods. As discussed above, nadir imagery can be used in many remote sensing software packages to perform land cover analysis (ESRI, n.d.-b). Research into using artificial intelligence (AI) landcover analysis is a potential future project with this imagery, as advancements in this field are always growing; ArcGIS has an array of deep learning AI software packages available that are user-friendly to those with little knowledge of AI (Fickas et al, 2023). Although determining a method of this for the GCA may be time consuming, once a framework is developed the data will be invaluable. This is especially true when further nadir imagery of the QH site is taken, so that landcover change can be compared through time. In regards to oblique imagery and landcover analysis, the Mountain Image Analysis Suite is a newly developed QGIS suite that works to georeference and classify land cover with oblique imagery of mountainous regions (Wright et al, 2024). It is proposed to develop a way to use this suite on low elevation imagery, which would allow the GCA to perform analysis on these images as well. With the collection of imagery from this study, land cover change and topographic relief change analysis could be possible.

If the GCA is interested in continuing to use nadir imagery in their repeat photography program, it would be beneficial to purchase a drone that is able to also perform LiDAR (Light Detection and Ranging) scans of the landscape, and collect data on multispectral bands. LiDAR point cloud data would allow the GCA to perform biomass surveying of tree and shrub height more efficiently; this is because the first and last response of the LiDAR point cloud can be subtracted to determine canopy height (ESRI, n.d.-c). These data can also be used to create both digital surface models and digital terrain models. If these scans could be combined with the process of collecting nadir data, this would be an interesting point of further research that would reduce surveying time. If the GCA is able to acquire a drone that can take imagery through multiple bands, the research applications are endless. The classic example would be performing a Normalized Difference Vegetation Index (NDVI), which uses the red and near infrared bands to quantify vegetation greenness (U.S. Geological Survey, n.d.). The NDVI gives insight into vegetation health and density, which may also work to reduce redundant field work; this calculation will help identify problematic areas on QH and other GCA properties, allowing field efforts to be directed to the locations most in need of attention.

Continuing to produce repeat photography products will allow the GCA to provide stakeholders and community members with information that is easily interpretable, which is also valuable to the GCA. These data will allow the GCA to perform further in depth analysis of the restoration site, and advanced equipment will allow the level of analysis to expand greatly.

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Appendices

Appendix 1.

Reference photography baseline photos using the GCA Photo Point technique. The image code and camera type are included for each point. The image code includes the site name (GBS: Great Beaver Swamp; QH: Quadra Hill), the project code (WR: wetland restoration), and the photograph number and associated letter for the photo point sets.

Image code: GBS_WR_P01A **Camera model**: Fuji X-T4 **Photography Type:** Focal Point

Image code: GBS_WR_P01B **Camera model**: Fuji X-T4 **Photography Type:** Focal Point

Image code: GBS_WR_P01C **Camera model**: Fuji X-T4 **Photography Type:** Focal Point

Image code: QH_WR_P03A **Camera model**: Fuji X-T4 **Photography Type:** Focal Point

Image code: QH_WR_P03B **Camera model**: Fuji X-T4 **Photography Type:** Focal Point

Image code: QH_WR_P04A **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P04B **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P04C **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P04D **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P05A **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P05B **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P05C **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P05D **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P06A **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P06B **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P06C **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P06D **Camera model**: Fuji X-T4**Photography Type:** Landscape

Image code: QH_WR_P06E **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P07A **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P07B **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P07C **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P07D **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Image code: QH_WR_P07E **Camera model**: Fuji X-T4 **Photography Type:** Landscape

Appendix 2.
Reference photography using the photosphere technology. The image code and camera model are included for each photosphere. The code includes the site name (GBS: Great Beaver Swamp; QH: Quadra Hill), the project name (WR: wetland restoration), and the associated photosphere number (for example, PS01 for photosphere image 1). Note, the photosphere images are distorted due to .JPEG file type.

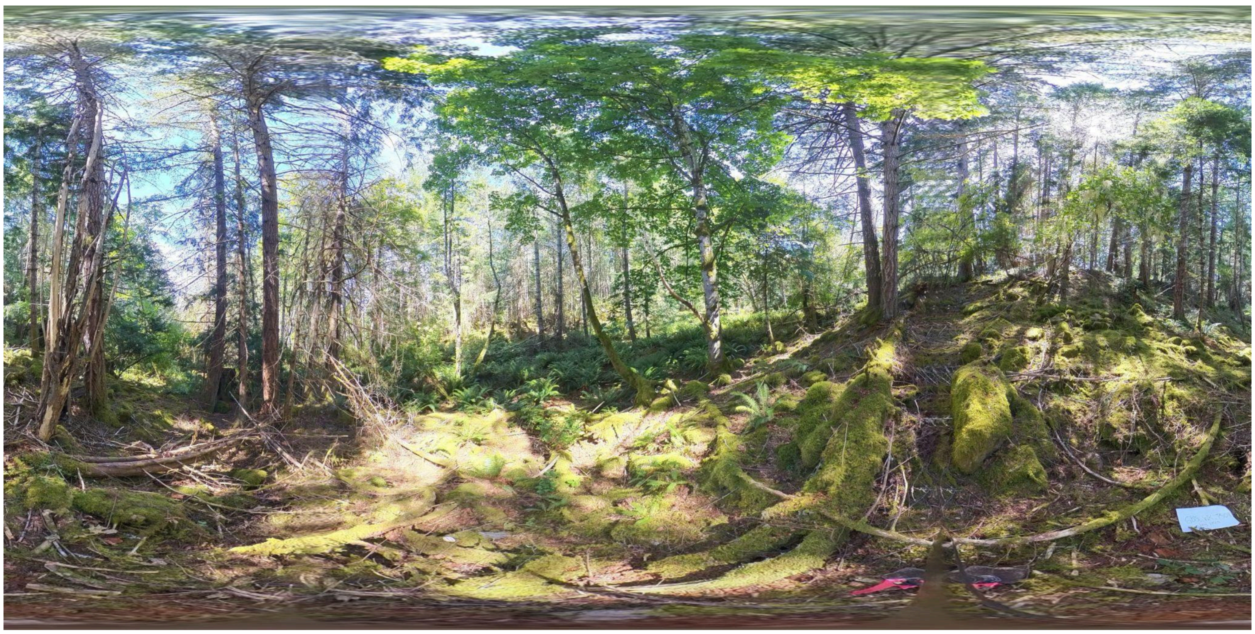


Image code: GBS_WR_PS01 **Camera Model:** Insta360

Image code: QH_WR_PS03 **Camera Model:** Insta360

Image code: QH_WR_PS04 **Camera Model:** Insta360

Image code: QH_WR_PS05 **Camera Model:** Insta360

Image code: QH_WR_PS06 **Camera Model:** Insta360

Image code: QH_WR_PS07 **Camera Model:** Insta360

Appendix 3.

Drone photography images taken on the DJI Mavic 3, owned by Dr. Eric Higgs. The drone was capable of taking 20mp nadir still imagery with sub 0.5m spatial accuracy. Imagery was taken at approximately 220m elevation above sea level, and 120m above ground level.

Drone Image 1. Aerial view of the entire QH wetland restoration site.

Drone Image 2. Aerial view of the entire QH wetland restoration site.

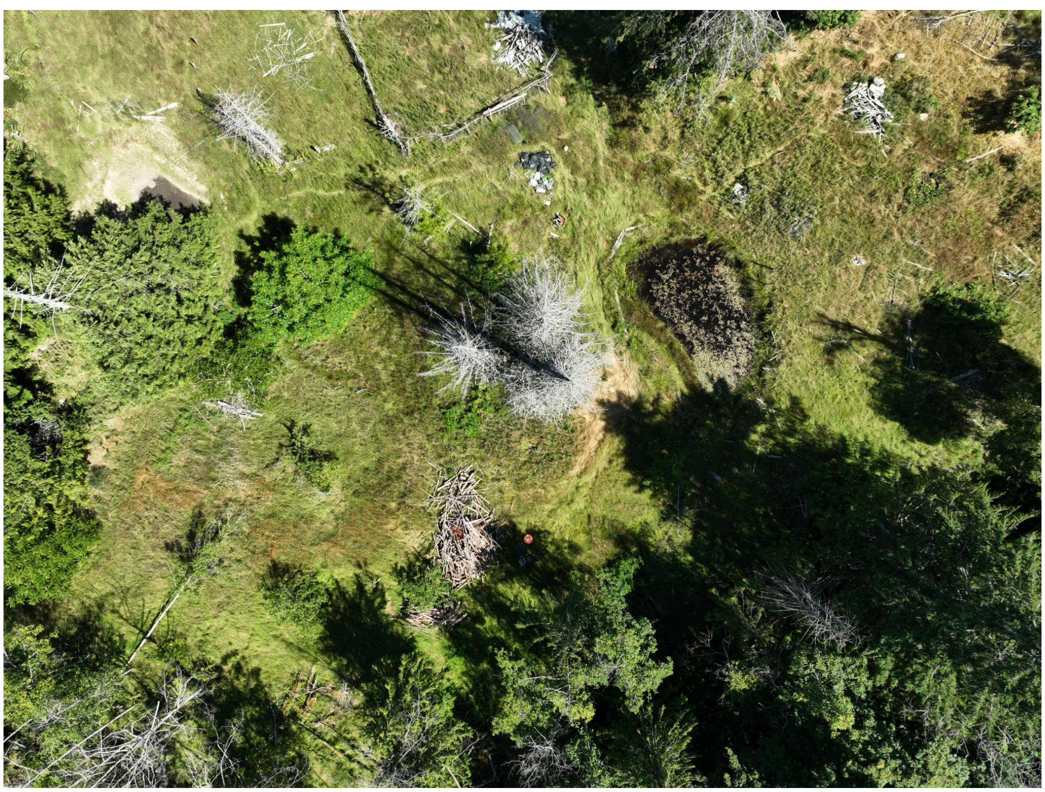
Drone Image 3. Aerial view of the entire QH wetland restoration site.

Drone Image 4. Aerial view of tree cover area in QH wetland restoration site.

Drone Image 5. Aerial view of tree cover area in QH wetland restoration site.

Drone Image 6. Aerial view of tree cover area in QH wetland restoration site.

Drone Image 7. Aerial view of tree cover area in QH wetland restoration site.



Drone Image 8. Aerial view of snag in QH wetland restoration site.