Remotely Piloted Aircraft Systems: A tool to support coastal climate change adaptation in Nova Scotia

By

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Submitted in partial fulfillment of the requirements for the degree

of

Master of Marine Management

at

Dalhousie University

Halifax, Nova Scotia

December 2019

ABSTRACT

Remotely Piloted Aircraft Systems (RPAS), more commonly known as “drones”, are being increasingly utilized to assist with civilian tasks. The rapidly developing technology offers a host of current and potential applications at lower costs than other forms of hyperspatial data collection. This research investigates the uses of RPAS as a tool to support coastal climate change adaptation strategies in Nova Scotia. Whilst anthropogenically induced climate change is a ‘wicked’ problem on the global scale, localized impacts affect natural and social systems across the region, necessitating adaptative strategies and tools. A RPAS was used to create 3D map layers of two coastal sites in the Port Mouton region of Queens County, Nova Scotia: a working wharf and a sandy beach within a Provincial Park. The data was displayed as 2D and 3D maps and used to support interviews with a variety of stakeholders, including community members, non-governmental organisations (NGOs), academia and government. Findings suggest that compared to imagery from Google Maps™, the RPAS maps provide high-quality visualizations that can enhance public perceptions of the risks posed by climate change. This paper presents a holistic perspective of the use of RPAS imagery so that the resulting visualizations can be used not only to communicate the impacts of climate change, but also to support management decisions and adaptation measures and policies. If the technical and legal limitations associated with RPAS operations are carefully considered and incorporated into pre-flight plans, RPAS can be used for various site-specific applications, providing a tool to assist with coastal adaptation strategies.

Keywords: Remotely Piloted Aircraft Systems; climate change visualizations; adaptation strategies; coastal management; Nova Scotia.

ACKNOWLEDGEMENTS

There are many individuals to thank, without whom this project would not have been possible. Firstly, I would like to thank all the participants of my study and the others that shared their knowledge or offered suggestions throughout the project.

Thank you to Oceans North for the opportunity to carry out this research – particularly Colleen Turlo for her guidance and support. A huge thank you to my supervisors; Claudio Aporta and Danika van Proosdij. As well as to Maxime Lapierre for all his assistance and for inspiring me with his love for drones.

Finally, I would like to thank my classmates from the Marine Affairs Program, I am very grateful to have shared this experience with you all.

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1. INTRODUCTION

Remotely Piloted Aircraft Systems (RPAS) are a rapidly advancing technology offering a plethora of applications; over the past ten years the commercial and recreational use of RPAS has increased exponentially (Lorah et al., 2018). While RPAS are known under several names, they are referred to most commonly as 'drones', and often associated with stunning aerial photography. However, RPAS are being increasingly utilized to assist with civilian tasks, including conservation, transportation, communication, agriculture, disaster mitigation and emergency response (Floreano & Wood, 2015), as well as for scientific research (Milas et al., 2018). In the context of marine management, RPAS are providing a cost-effective tool that can assist with wildlife monitoring, coastal and shallow-water ecosystem mapping and identifying and documenting coastal hazards (Rees et al., 2018), to name a few. The data RPAS collect can be used to inform management decisions, therefore, given the continued growth of the technology, investigating the current and future uses for RPAS in marine management seems timely.

A major priority for the management of marine and coastal resources is mitigating the impacts of anthropogenically induced climate change, a phenomenon that is causing discernible impacts on natural and human systems worldwide (Hansen & Stone, 2016), and providing tools to assist with adaptation. Impacts from climate change and sea-level rise are particularly important for coastal communities where flooding and erosion are predicted to increase (Chouinard et al., 2008), as well as intensity and frequency of storms. Certain parts of the Canadian Atlantic coast are particularly vulnerable to storm surges and rising sea-levels; in Nova Scotia, sea level rise as a consequence of human induced climate change is occurring and predicted to occur at higher rates than the global average (James et al., 2014). Sea level rise due to the expansion of warming waters is accentuated by the low-lying topography found in the province and the high rates of coastal subsidence (Savard et al., 2016). In the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) under a 'business-as-usual' scenario of carbon dioxide emissions (A1F1), on average Nova Scotia is predicted to receive 1.79m of sea level rise by 2100 (Richards & Daigle, 2011). In this context, this project aims to explore the suitability and potential applications of RPAS as a tool to assist with climate change adaptation for coastal communities, through their ability to create accurate and cost-effective 3D maps of coastal areas.

The study region for this project was Port Mouton Bay in Queens County, southwest Nova Scotia. A predominantly rural region within the Southwest Nova Biosphere Reserve, it is populated by small fishing communities. Here the Atlantic coastline is of relatively low elevation and supports a diverse array of habitats and ecosystems, such as sand dunes and intertidal flats. Several coastal sites have been recognized for their ecological importance and designated as protected areas; they include Kejimkujik Seaside National Park, Port Joli Provincial Bird Sanctuary and Carters Beach pending Nature Reserve. The low elevation coastline of the Port Mouton Bay region renders it susceptible to the impacts of sea level rise and storm surges. Community members are already observing the effects of climate change, including breaches of sea walls and roads and eroding sand dunes (Ross, 2018). In 2018 a public participatory GIS mapping workshop was held in Port Mouton to map the effects of climate change; the results can be seen on the Port Mouton Bay Asset Map. The Region of Queens Municipality has also identified areas that are particularly vulnerable to SLR in the Municipal Climate Action Plan, with several located in the Port Mouton Bay region, including St. Catherine’s River Road in Port Joli and Burgess Road in Port Mouton (Region of Queens, 2014).

Sea level rise as a result of climate change can damage property and public infrastructure near the shore, as well as sensitive ecological systems that act as significant habitats for species at risk, including sand dunes and salt marshes. The piping plover is an endangered species that spends its summer breeding season on sand dunes along Nova Scotia’s Atlantic coast (Environment Canada, 2012), including beaches along Port Mouton Bay. Unfortunately, last year less than 40 breeding pairs were sighted in Nova Scotia (Bird Studies Canada, 2018), and the vulnerable low-elevation sandy beaches they require for nesting habitats are vital for the continued recovery of this threatened species. Climate change can exacerbate coastal erosion and lead to loss of salt marsh environments, which are among the most productive and unique ecosystems in the world (D’Entremont et al., 2018). Salt marshes provide coastal protection, acting as buffers from storm surges by attenuating wave energy (Duarte et al., 2013; van Proosdij & Page, 2012). They are also highly effective carbon sinks that offer a unique source of ‘blue carbon’ (Wollenberg et al., 2018).

In addition to the environmental and ecological impacts the region is susceptible to, the impacts of climate change can have economic and social implications. Like multiple rural communities across rural Nova Scotia, the local economy is largely supported by fishing. The fishing industry is already being impacted by climate change, storms damage gear and wharves which leads to fewer days out on the water (Ross, 2018). Less directly, higher water temperatures are affecting the migration of commercial fish and in some cases lead to the introduction of potentially destructive invasive species. Ocean acidification is also affecting commercially valuable shell-building seafood (Savard et al., 2016). The effects of climate change only exacerbate the impacts of overfishing on vulnerable fish populations (Halpern et al., 2015), requiring increased resilience and adaptation capacities from coastal communities. The Port Mouton Bay community is actively engaged in climate change adaptation and ecological protection, often through the volunteer community group Friends of Port Mouton Bay. The actively engaged communities and the fact that this region is representative of many rural coastal regions in Nova Scotia, with unique ecosystems and rural livelihoods that are susceptible to the impacts of climate change, made the Port Mouton Bay area a clear choice for this study.

1.1. Research Questions

In order to explore the suitability and potential applications of RPAS as a tool to assist with climate change adaptation for coastal communities in Nova Scotia, this study addressed the following research questions:

1. How can maps that use hyperspatial imagery affect people's perception of coastal vulnerability to sea level rise and other impacts of climate change?

2. What are the advantages and limitations of using RPAS to create coastal maps in Nova Scotia?

3. What are the potential applications of these maps for coastal communities in Nova Scotia to complement current climate change adaptation strategies?

The research questions were explored through four key stages, beginning with a literature review on the use of RPAS to date for marine and coastal management, drawing from global sources where examples from Nova Scotia are lacking. Second, high resolution 2D & 3D maps, using aerial photography captured by RPAS, were created for two sites of interest in the Port Mouton and Port Joli region, representing different coastal ecosystems and degrees of human land use. Third, following the creation of the maps and the completion of the literature review, stakeholder interviews were conducted to explore the ability of the maps to influence people's perception of coastal vulnerability, and the potential applications of these maps for coastal communities in Nova Scotia to complement current climate change adaptation. Finally, the interviews and literature review were then used to support the study's discussion, as well as develop recommendations on the use of maps created by RPAS for coastal climate change adaptation in Nova Scotia, including any limitations to their usage. Further details on the methodology of this study are provided in Chapter 3.

2. LITERATURE REVIEW

Remotely Piloted Aircraft Systems is the most recent of a series of technical terms to describe drones, used in the Transport Canada regulations effective from June 1st, 2019 (Transport Canada, 2019a). Previously they were known as Unoccupied Aircraft Systems (UASs) and Unmanned Aerial Vehicles (UAVs) (Johnston, 2019); the progression in terminology is apparent when glancing through the literature spanning the last decade. UAV encompasses various configurations of unmanned aircraft; fixed-wing UAVs, rotary wing UAVs, blimps (which are low-flying, slow, long-endurance aircrafts), balloons and kites (Klemas, 2015). For consistency with the type operated during this project, RPAS will refer primarily to a rotary-wing UAV, which is the most commonly used configuration at present.

2.1. An Introduction to Remotely Piloted Aircraft Systems

Remotely Piloted Aircraft Systems (RPAS) have their origins in military operations. However, over the past decade their use has intensified and expanded across a variety of fields. Technological advances have improved performance, which combined with a thriving commercial and recreational market, have lowered costs and increased accessibility. Multiple sectors are recognising the opportunities that RPAS present, from the agricultural sector to law enforcement and emergency response (CBInsights, 2019; Santangelo et al., 2019).

Amongst the scientific community, there has been a surge in popularity in the use of RPAS for data collection (Hodgson et al., 2018); this can be seen in the fact that between 2013 and 2016 the number of journal articles focused on RPAS doubled (Lorah et al., 2018). This is predominantly attributed to their ability to carry remote sensing instruments that can be used to collect data at fine spatial and temporal resolutions, their relatively low operating costs, and the ease by which they can be operated and manoeuvred (their operational flexibility) (Klemas. 2015). Whilst they may provide the same overhead perspective as satellites or manned aircrafts, they in fact operate at a much lower altitude, capturing images with a greater level of detail (Joyce et al., 2018). As a result of these features, some authors have noted that RPAS are poised to revolutionize many aspects of marine science and conservation (Colefax et al. 2018).

2.2. Marine and Coastal Applications

RPASs have been cited as a tool that can facilitate scientifically rigorous data collection for wildlife population monitoring due to their high accuracy, precision, and lower bias than other approaches (Hodgson et al., 2018). They provide the opportunity to error-check results and collect population data without disturbance, as well as being able to collect standard and thermal imagery (Rees et al., 2018). For surveying marine megafauna, RPAS have in some cases already replaced manned aircrafts. RPAS surveys have been successful in documenting the spatio-temporal dynamics of an impressive suite of large marine fauna including large-bodied elasmobranchs, sea turtles and seals (Kelaher et al., 2019; Hensel et al., 2018). Their usage so far varies from obtaining population assessment and spatial variations in abundance, to assisting research into behavioural ecology, and providing health assessments for individuals (Johnston, 2019). Marine megafauna behavioural and ecological studies have the potential to gain significant value from the use of RPAS, especially in relation to foraging strategies, habitat associations, social patterns, and response to human disturbance. One use that is currently being explored is developing video behaviour analysis methods from footage obtained of large marine mammals, such as whales (Torres et al., 2018).

The application of RPASs for scientific research in marine and coastal environments is not solely limited to surveying marine megafauna. They can also be used to collect physical samples, including water and sediment, marine aerosol samples over the ocean, and whale respiratory vapor (Johnston, 2019). Another application is that of marine litter detection; the Plastic Tide Marine Litter DRONET is working on a simple, repeatable and accurate method for surveying coastal marine litter (Kohler, 2018). Some of these applications have the potential to reach further than just assisting with scientific research, where the RPAS can be used to help alleviate the impact of humans on the marine environment, be it through conservation or assisting the removal of plastics from the ocean.

RPASs can be used in real-time to rapidly identify and document coastal hazards, such as oil spills, rapid coastal erosion, or marine mammal stranding events (Johnston, 2019). Their low cost and high operational flexibility mean that flights can be undertaken frequently and on demand. As a result, their use in response to specific natural and anthropogenic events, such as storms or oil spills, has increased (Rees et al., 2018). In the management context, RPAS surveys can be useful as surveillance platforms that patrol areas to detect illegal or unpermitted activities (such as fishing or poaching), as enforcement tools whereby they loiter over potential violators and guide enforcement efforts, and as a behaviour modification tool where consistent aerial surveillance reduces illegal activities (Rees et al., 2018). Marine protected area surveillance systems have been proposed that incorporate the use of RPASs to monitor the marine protected area against illegal vessels (Arefin, 2018). However, using RPASs to observe human activities raises questions of privacy and ethics, and the regulations and restrictions on where and over whom RPAS can be flown varies between countries.

In coastal and shallow-water marine areas, RPAS can be used for mapping or modelling sites, and to capture changes to the landscape or habitats. The high resolution that they afford allows for species-level vegetation mapping. RPAS with multispectral cameras can map over a variety of shallow-water marine habitats, such as nursery areas, tropical reefs, salt marshes, mangrove habitats and estuaries (Ventura et al., 2016). They are an excellent tool for monitoring systems' dynamics, as they can be dispatched to photograph the same landscape repeatedly (Lorah et al., 2018), as well as providing evidence-based habitat conservation and management (Rees et al., 2018). While single surveys provide only snapshots of the landscape displaying habitats and plant species distribution, repeated surveys using computer applications can generate time-series imagery data than can be used to monitor habitat change, such as in the wake of a coral bleaching event (Rees et al., 2018). The use of RPAS also allows for monitoring longer-term topographic changes along the coast.

An example in which RPAS act as a burgeoning tool for coastal dynamic studies, is their use to remotely sense coastal topography and morphology, through the creation of accurate Digital Surface Models (DSMs), or Digital Elevation Models (DEMs). Beach surveys can be replicated routinely, in under a few hours, at a high resolution using an automatic flight plan procedure, therefore addressing large-scale morphological evolution at high temporal resolution (Laporte-Fauret et al., 2019). Not only is this useful for documenting changes, for instance after a storm, but DEMs that accurately model coastal topography can also be used to project the impacts of predicted sea level rise. Varela et al., (2018) used DEMs created by RPAS to project sea level rise scenarios and assess the future vulnerability of a key nesting habitat for loggerhead and green turtles, at a rookery in the Mediterranean. A similar technique can be used to project the impacts of sea level rise or storm surges on coastal infrastructure. Mapping, monitoring and predicting changes, such as sea level rise, can be of great use to the communities that reside or rely on the coast, and they are crucial for undertaking management decisions and promoting climate resilience.

2.3. Creating maps with RPAS

In order to create DEMs of coastal areas, the high-resolution remote sensing images captured by RPAS are processed by photo-based 3D reconstruction software to create data layers that can be exported for use in Geographic Information Systems (GIS) (Hansman & Ring, 2019). Chapter 3 provides a detailed methodology for this project, following a standard RPAS data collection workflow that includes a preflight plan and follows a safety checklist. Using RPAS for this purpose is by no means limited to coastal regions and is practiced over a variety of terrestrial terrains; RPAS photo-based 3D reconstruction mapping has been found to be 'an accurate and cost-efficient remote sensing method for geological mapping' (Hansman & Ring, 2019).The maps, or DEMs, created are detailed orthomosaics which can produce near centimetre accuracy, providing a higher level of detail than satellite-derived or manned-aircraft imagery (Rees et al., 2018). In fact, following recent developments in technology, some sources regard RPAS as the third generation of platforms generating remotely sensed data of the surface of the Earth (Milas et al., 2018).

2.4. Technical considerations

When it comes to using RPAS for environmental remote sensing, their relatively short flight time remains the primary challenge (Hardin et al., 2019). Most lightweight RPAS systems are powered by lithium polymer (LiPo) batteries, which are a relatively expensive component in RPAS and pose a significant fire risk (Duffy et al., 2017). The batteries have a finite lifespan, which can vary depending on flight conditions, and need regular recharging thus limiting the time that research can be carried out away from a power source. Problems related to battery power constraints can to some extent be mitigated by careful mission planning, which can be done using software that provide detailed flight plans (Hardin et al., 2019). Where data collected by RPAS is being used for scientific research or to inform management decisions, control targets or monuments should be surveyed within the flight path in order to ensure the accuracy and precision of the DSMs produced. The spatial distribution and the quantity of these targets can greatly affect the accuracy. The data collected also requires lengthy post processing, requiring appropriate software and experienced technicians. Additionally, as most RPAS are equipped with standard RGB cameras (Green et al., 2019), dense vegetation will obscure the ground in the resulting imagery. In temperate regions flying during seasons with little vegetative cover, such as early spring, can yield accurate results. Otherwise if photogrammetric reconstruction of bare earth topography is required, an alternate platform, such as LiDAR, may be preferred (Varela et al., 2018).

Whilst there are still several other technical considerations to be aware of, technological advances over the past ten years have improved the ability of the operator to respond to challenges, as well as decreasing the magnitude of those challenges (Hardin et al., 2019). However, although advanced flight controls and obstacle avoidance capabilities have improved flight safety and aircraft survival (Hardin et al., 2019), RPAS are not suitable to fly in extreme weather conditions. Wind gust conditions, sea salt spray and small particles of airborne sand, with the potential to damage RPAS engines, are all potential limitations (Varela et al., 2018). High wind can also cause features to move between images leading to difficulties with data analysis, this is of concern when dealing with vegetated sand dunes and as such wind speeds and directions must be considered (Duffy et al., 2017). Pre-flight planning is required to avoid hazardous weather conditions and to identify a suitable take-off and landing area, which can be challenging at coastal sites (Duffy et al., 2017). Although RPAS can be used to access terrain that can be challenging to navigate or with high relief, such as mountainous or coastal cliffs (Hansman & Ring, 2019, Santangelo et al., 2019), they cannot access hugely remote locations, as the pilot must always be in range of the RPAS (Transport Canada, 2019a). Another consideration to be accounted for is that when flying over water additional flight planning is required to time the flights so that sun glint or subsurface illumination do not affect the quality of images. Sun glint (or sun glitter) occurs when light is reflected back to the sensor by the surface of the water, obscuring what is beneath it (Joyce et al., 2018).

2.5. Legal requirements

Beyond the technical considerations addressed above, operators must ensure that they have all necessary permits and licenses. For remote sensing data gathered from satellite, researchers are in most cases not involved in the original data collection. However, for the majority of research projects using RPAS, data collection is undertaken by members of the research team. As such, it is of utmost importance that when a RPAS is used to gather data jurisdictional legal requirements are followed. Furthermore, licenses and third-party insurance must be obtained, and the operator must be legally qualified to fly the RPAS (Milas et al., 2018).

The usage of RPAS has potential negative impacts on privacy, security and safety, and strict regulations are required for their operation. There have been little restrictions to RPAS purchasing to-date, and, as a result, usage has generally outpaced the development of adequate regulatory frameworks (Rees et al., 2018). In Canada, as of June 1st, 2019, new legislation on the use of RPAS has been implemented. The regulations differ depending on the type of pilot, the size of the RPAS, the area of operation and the proximity to bystanders (Transport Canada, 2019b). Within the new policy framework, RPAS pilots must follow the Canadian Aviation Regulations (CARs) which apply to devices up to 25 kilograms; these regulations state that pilots must carry a valid RPAS pilot certificate and only fly devices that are marked and registered (Transport Canada, 2019a). There are certain areas that, within the new legal requirements for RPAS flights, require advanced pilot certifications that are noticeably more challenging to obtain. The use of RPAS in marine management must abide by the evolving legislation and local regulations governing the use, which is a major consideration when undertaking research as it requires careful pre-survey planning (Varela et al., 2018).

2.6. Social considerations

Another dimension of operating RPAS responsibly in research is to ensure social license is given. This is sometimes complicated by the fact that public perception of RPAS is often associated with noise disturbance, the fear of privacy invasion and a mistrust of motives. RPAS have historically been associated with military applications and intelligence gathering, in some cases prompting citizens to mistrust the motives of RPAS operations. In order to minimise the negative connotations associated with their usage, transparency is of paramount importance. Public trust can be gained through good communication with stakeholders whilst collecting, storing and using data (Duffy et al., 2017). As with all relatively new technologies, there is still little research done on the social implications of RPAS usage as they are a relatively new phenomenon in civilian use. As such, as well as abiding by local regulations, site-specific self-regulation is central to the success of research projects that use RPAS for data collection (Rees et al., 2018). As is the case with any scientific research, the use of RPAS must also follow good ethical practices. Where maps created by RPAS, or indeed any RPAS research, are used to communicate climate change or for other conservation purposes, there is the risk that the aforementioned negative social perceptions can undermine the effectiveness of the endeavour (Sandbrook, 2015).

2.7. RPAS in Nova Scotia

Whilst there is little published literature on RPAS specific to Nova Scotia, over the past few years the regional use of RPAS has increased as the technology develops and gains popularity. Several organizations have in fact been successfully utilizing RPAS in various forms for coastal applications over the last ten years, examples of which will be highlighted in the following section. Currently in Nova Scotia, the Applied Geomatics Research Group (AGRG), based out of Nova Scotia Community College, incorporate the use of RPAS for mapping and engineering projects (N. Crowell, personal communication, 2019), as do several private engineering and consulting companies. One interview participant (further interview details are given in Chapters 3 and 4), commented on how the Nova Scotia Department of Energy and Mines use RPAS to capture 3D models of coastal sites, to determine erosion rates and how the underlying geology can affect these rates, as well as to monitor changes over time. RPAS can determine subtle changes, or areas of erosion, in the cliff faces and offer a more holistic view than 2D aerial photos.

Using similar techniques, RPAS are being utilized as a tool to assist with climate change adaptation strategies in the Bay of Fundy, Nova Scotia. The Department of Fisheries and Oceans (DFO) is funding saltmarsh restoration - a nature-based technique to help absorb rising sea levels and storm surges, that involves realigning and decommissioning dyke infrastructure (CBC, 2018). The project is led by Saint Mary's University, in partnership with CB Wetlands & Environmental Specialists and Nova Scotia Department of Agriculture. As part of this project, RPAS are being used to develop contemporary snapshots showing site conditions; a view of the sites from the oblique for reference; to identify erosion and overtopping; and to inspect coastal infrastructure (C. Ross, personal communication, 2019). The DSMs and DEMs generated are also used for flood modelling and spatial patterns of flooding when tides return, providing an accurate areal extent of the tidal wetland being restored.

Other organizations that have begun to utilize RPAS include the Bedford Institute of Oceanography and the Dalhousie Oceanography department, to detect changes in the intertidal zone and rates of cliff retreat, respectively (van Proosdij, personal communication, 2019). Dalhousie School of Engineering operate a RPAS equipped with thermal sensors in order to detect cold-water habitats in rivers and estuaries and zones of groundwater discharge, the RPAS function as a useful tool for the ongoing research into saltwater intrusion and groundwater sensitivities to climate change (Dalhousie Groundwater Lab, 2019). Most of the coastal applications for RPAS in Nova Scotia are still in their infancy, however, the innovative uses of RPAS discussed here pave the way for their use in future research and climate change adaptation strategies in Nova Scotia.

3. METHODOLOGY

Recognizing that the impacts of climate change will increasingly be affecting Nova Scotia, it is a pertinent time to explore the potential applications of burgeoning technologies to support adaptation strategies. Strong communication of climate change is necessary in order to foster social change and facilitate community support for these strategies. Visualizing and localising the impacts is imperative to communicating climate change, as suggested by visualization theory (Sheppard et al., 2008). In recognition of the value of visualization in communicating strategies, this research aims to assess the ability of RPAS maps to communicate and enhance perceptions of the impacts of climate change. Additionally, through visualization techniques, other applications of RPAS technologies are also explored.

Within this research a mixed methods approach was adopted to investigate the appropriate uses of RPAS as a tool to assist with climate change adaptation for coastal communities. The project began with a general literature review of the coastal uses of RPAS (reflected in chapter 2), in Nova Scotia and further afield, before identifying two coastal sites to be mapped in Nova Scotia (see below). This chapter will outline the methodology employed for the RPAS operations, including the pre-flight plan, the flights and the processing required to produce 3D geospatial data. It will then cover the stakeholder interviews conducted, using the newly created data, to assist in addressing the research questions. The interviews were structured in such a way as to address these questions; investigating how the maps created by the RPAS can communicate the impacts of climate change and affect the viewers perceptions of the issues, and gathering the participants views on the advantages and disadvantages of utilizing RPAS, as well as potential applications in Nova Scotia. When combined with findings from the literature review, these responses provided content for the project discussion.

The project was undertaken as part of an internship with Oceans North. The Canadian organization puts emphasis on community driven projects and partnerships with organizations and communities that support ecological resilience and abundance (Oceans North, 2019). As Oceans North expand their work into Atlantic Canada, they are working with coastal communities engaged in sustainably managing the marine environment and the social systems it supports. Such a focus is increasingly important in the context of climate change. Located in rural Nova Scotia and home to small coastal communities reliant on marine resources, Port Mouton Bay is one region that may experience significant climate change impacts. Oceans North was able to facilitate community involvement with the research, by connecting the researcher with contacts in Port Mouton Bay, as well as providing support and guidance throughout the project.

3.1. Site Identification

In order to identify two appropriate sites to map with the RPAS, a shortlist of potential sites was created of locations in the Port Mouton/Port Joli region of Queens county, Nova Scotia (Appendix I). The shortlist was created with the assistance of Oceans North and feedback from some community members. Criteria for inclusion in the shortlist were that the sites suggested represented infrastructure identified as vulnerable to climate change in the Queens Municipal Climate Action Plan (MCAP), areas identified as “community assets” in the Friends of Port Mouton Bay Asset Map, or coastal ecosystems that provide habitat for species at risk in the region. From this shortlist two sites representing different coastal uses were chosen, based also on the feasibility of operating a RPAS at the sites. The sites were easily accessible with locations that the operator or crew members could stand so that the RPAS was always in line of sight. Additionally, the flight areas did not cover roads or paths that experience large volumes of pedestrians and passing vehicles, to keep the operations away from bystanders and adhere to Transport Canada regulations (Transport Canada, 2019a).

The sites chosen were Port Mouton Central Breakwater and a coastal stretch of Thomas Raddall Provincial Park. The two sites represent different aspects of Nova Scotia’s coastline; human infrastructure with economic and social importance for the surrounding communities, and coastal environments largely untouched by humans. Whilst the sites vary considerably, they are both directly and indirectly vulnerable to the impacts of climate change. The Port Mouton wharf is utilized year-round by commercial and recreational fisherman and was identified as a “community asset” within the Friends of Port Mouton Bay Asset Map (Ross, 2018). Thomas Raddall Provincial Park contains numerous coastal ecosystems, including sandy beaches and salt marshes, that provide ecosystem services and significant habitats for several species at risk.

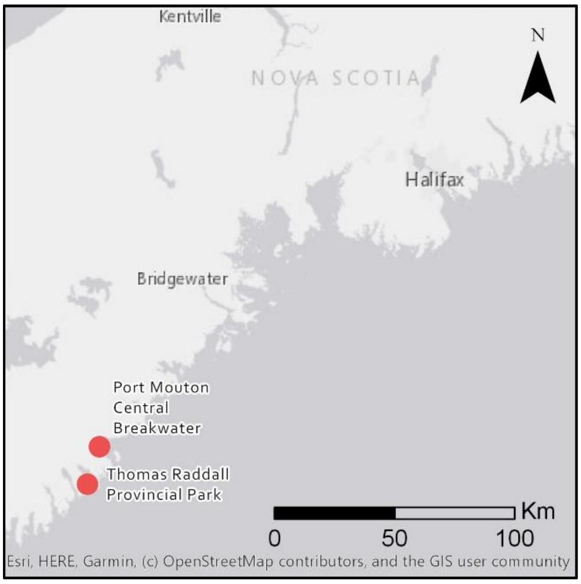

Figure 1 *- The locations of the two sites in relation to Halifax, Nova Scotia.*

3.2. RPAS Operations

To create maps of the chosen sites using imagery captured by a RPAS, there were several methodological stages to be executed. Figure 2 depicts a RPAS data collection workflow by Joyce et al., (2018); the generic procedures listed were the basis of the methodology used to create the maps with the RPAS, in conjunction with recommendations from the RPAS operator.

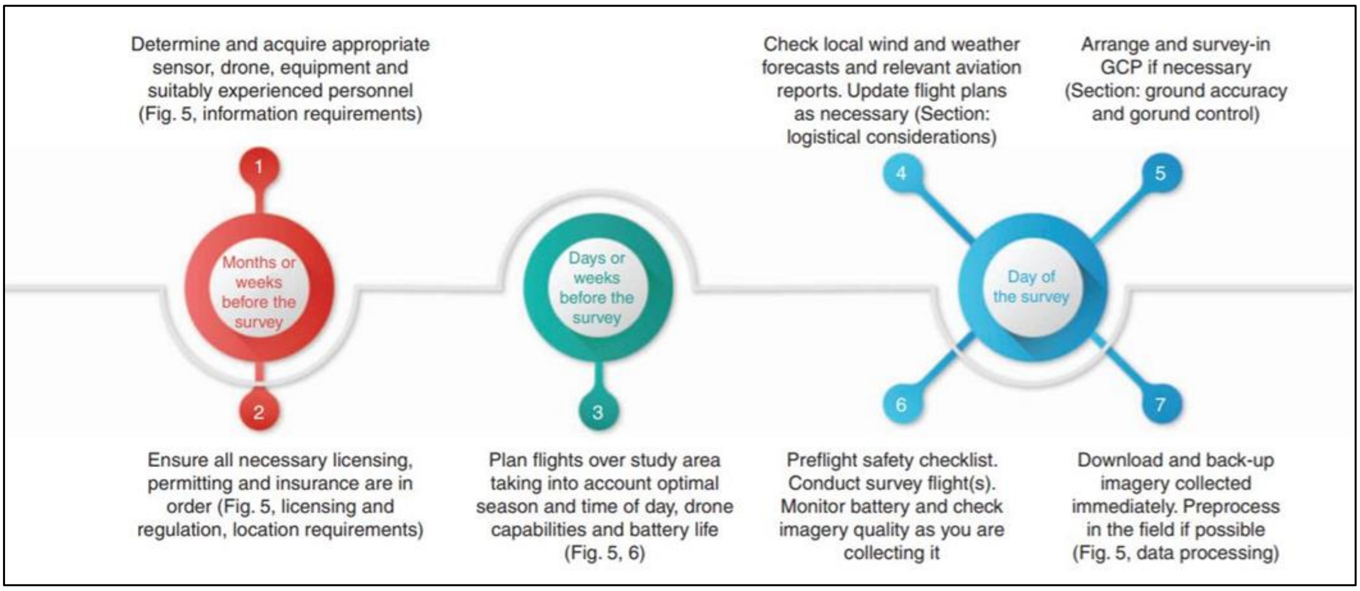

Figure 2 *– The drone data collection workflow and the estimated time frame for each step, from Joyce et al., (2018) (GCP – Ground Control Point).*

Pre-flight planning is crucial to ensuring that the RPAS is deployed safely in the field, including a pre-flight site check via a desk-based assessment and a survey of the immediate surroundings once on site (Duffy et al., 2017). The necessary permissions for the flights were obtained along with all permits required for the operation of the RPAS. This part of the project was conducted with the support and equipment of the Marine Affairs Program's MAP Vis Lab (at Dalhousie University). Pre-flight plans were created for both sites selected, considering total flight time, low tide times, take-off and landing locations and locations for public signage. The exact areas that the RPAS would operate within were delineated (Figure 3 below), the flights areas were slightly larger than the actual region originally proposed, as recommended by Joyce et al., (2018) to ensure that the features of interest were sufficiently captured.

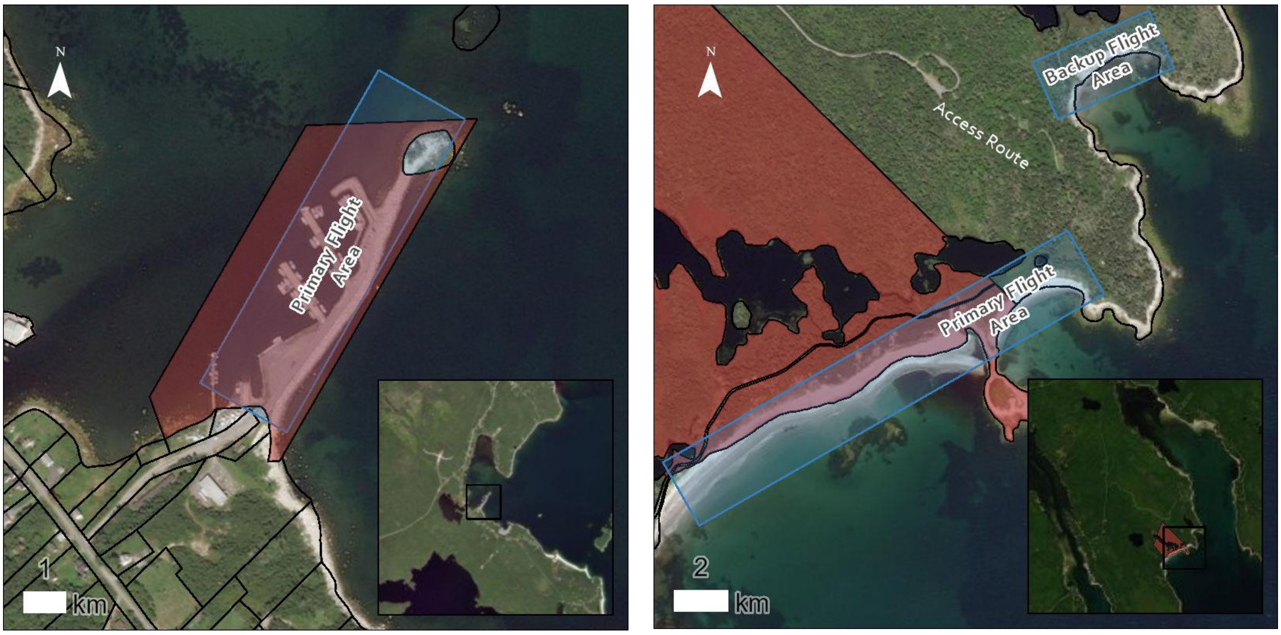

Figure 3 *– The flight areas for the RPAS operations: Left – Port Mouton Breakwater, Right – the beach adjacent to Thomas Raddall Provincial Park.*

During the flight operations, field procedures tailored to the locations were followed, which involved completing a pre-flight safety checklist (Appendix II). Immediately prior to commencing flight operations, each site was surveyed in person to ensure that the RPAS could be safely operated - one of the flights was in fact postponed until the following day due to wind conditions. In-keeping with Transport Canada regulations (Transport Canada, 2019b), two crew members were present alongside the RPAS operator to ensure the device was in line of sight during the flights and to alert and engage with bystanders where required, in addition to the signage displayed at public entrances to the flight areas. Recognising the risk of negative social perceptions to RPAS operations, this methodology ensured operational transparency and open communication with any potential bystanders.

Whilst operating, rotary wing RPAS are controlled via two main mechanisms than can be employed in tandem; a remote-control operated by a ground-based pilot, or an autonomous flight following predetermined routes generated using a flight control software, often located on a computer or tablet (Rees et al., 2018). In this case the flight control software (DroneDeploy) that was used to delineate flight areas also executed the flight, this included the appropriate image acquisition timing. Flight control software also ensures that the images collected adequately overlap, which is crucial to generating 2D and 3D geospatial data. The images were collected as geotagged .jpg files using the electro-optical sensor, essentially a digital camera, which is attached to the RPAS.

The degree of overlap for the images collected was 75% front and side overlap for both sites. The RPAS was operated at 43m above ground level (AGL) for the Port Mouton central breakwater (at 30m AGL over the wharves and 24m AGL over the armour rock breakwater), and at 61m AGL in the Thomas Raddall Provincial Park site. The ground sample distance for Port Mouton central breakwater was 1.3cm (with the wharves and armour rock at 1cm) and 1.8cm for the sandy beach site, translating to the same resolution for the imagery. The wharves and armour rock at the Port Mouton breakwater were areas of interest with complex 3D terrain, requiring higher resolution imagery to be collected.

Once the RPAS had collected the multiple overlapping aerial photos, the images underwent post-flight processing. Using the Agisoft Metashape software, they were merged into a 3D model using a computer vision technique known as photogrammetry, or bundle adjustment (Varela et al., 2018). The software generated both 2D and 3D map layers, including DSMs, orthomosaics, colorized point clouds and textured meshes (Lorah et al., 2018). In this form, 3D textured meshes of both sites alongside 2D birds-eye maps were used as the basis of the stakeholder interviews, there was no further analysis (i.e. hazard layers) undertaken on the geospatial datasets.

3.3. Stakeholder Interviews

Semi-structured interviews were carried out in August 2019 (n=9), with approval from the Marine Affairs Program Ethics Standing Committee (MAP2019-08). During the interviews the participants were asked a series of semi-structured questions (Appendix III) with the objective of investigating how the maps created with the RPAS imagery can communicate climate change and assist adaptation. Although most participants were already familiar with the area displayed in the maps, they were shown Google Maps™ aerial imagery of each site (with 50cm resolution), then asked to comment on the threats that the site may be facing and their opinion on the vulnerability of the sites to the impacts of climate change. Google Maps™ was used as a reference for this study as it is the most commonly used mapping platform, available publicly worldwide and easily accessible. In a second stage of the interview, participants were shown the maps created with the RPAS and asked the same set of questions. When viewing both sets of maps, participants were able to pan and zoom as they wished, therefore viewing the sites at different scales. The third part of the interviews consisted of a series of questions to identify any benefits the participants anticipated the coastal maps providing for different stakeholders, or any potential issues that could arise with RPAS operations. The interviews structure was designed to a) observe any changes to participants perceptions of coastal vulnerability to climate change depending on the type of imagery they interacted with, and b) explore the potential applications of the maps created from the RPAS imagery to complement current climate change adaptation at the provincial, municipal and community level.

The interviews were conducted with participants representing a variety of groups with interest in the area (or stakeholders), including community members (n=2), environmental non-governmental organizations that work locally (n=2), academia (n=1), planners for municipal governments (n=2), a provincial resource manager (n=1) and a geologist working for the provincial government (n=1). The participants were identified using snowball sampling from a few key contacts in the region provided by Oceans North. While a diversity of stakeholders was chosen in order to provide a broader assessment of the potential applications of the maps, a high number of participants was not deemed necessary in order to explore the use of a new visualization tool and compare the results with existing literature.

In order to assess the potential of the visualizations that the RPAS maps can provide, a content analysis was undertaken to identify themes and codes that arose throughout the interviews. Once transcribed, the researcher identified codes and themes from the interviews that fell under the three research questions, following multiple read-throughs of the data.

3.4. Limitations

Methodologies detailing the logistics of RPAS operations are starting to become more prevalent in the literature. However, the rapidly developing nature of the technology, coupled with its increasing usage in scientific research, necessitates flying protocols to be frequently updated in order to remain current. The flights conducted in this research did not utilize Ground Control Points (GCPs), that would have increased the accuracy and the precision of the Digital Elevation or Surface Models produced, as there were few publicly available flying protocols, including the use of GCPs, found in the literature. The timeframe in which the project was completed was not sufficient in order for the MAP Vis Lab to be able to develop their own GCP protocol for the flights. Luckily for the purposes of this study, investigating how the RPAS maps can influence perceptions to the impacts of climate change, GCPs were not required. Moving forward, in order for the data collected to be of use to the widest range of applications and contain accurate topographic information, future studies should include GCPs.

As mentioned above, the use of RPAS is not appropriate for large-scale surveys, which significantly reduces the area that can be mapped. The current batteries do not support long flights; in fact, most RPAS are limited to roughly 20 minutes of flight per battery. The flight area is further reduced by the necessity for the RPAS to operate at lower altitudes - higher altitudes affect the image resolution as most RPAS cameras have a fixed focal length (Lorah et al., 2018). Although in this research these considerations were accounted for in the pre-flight plan, the features that could be mapped by the RPAS were limited to those that fit within the radius the RPAS could operate in. Even with a small flight area, during the data processing the large data files collected by the RPAS incurred lengthy processing times – another consideration when utilizing RPAS for the creation of coastal maps. The technical limitations noted here were identified during the planning stages of this project and therefore could be accounted for within the pre-flight plan. This meant that the results of this research did not suffer from any unanticipated changes brought about by the limited flight time or lack of GCPs for the RPAS flights.

Several steps were taken in order to address potential biases that may arise from stakeholder interviews. Although there was a small number of participants, the variety in backgrounds afforded a wide breadth and depth of perspectives. Bias could also arise because all participants interviewed were already interested in the topic and/or have had experience working with RPAS. To account for this potential bias, all participants were given ample time to discuss and reassess the imagery presented to them, to gain a more detailed impression of what the maps can provide. Further, interviewing individuals who have previously utilized RPAS also provided insights associated with a higher level of expertise. Another potential limitation of this work is that the questions used for the semi-structured interviews were designed by the researcher to elicit answers on specific topics, which could impose researcher bias on the outcome of the interviews based on the questions that were asked. To account for this, the semi-structured nature of the interviews allowed for flexibility in responses, and the questions were mainly used to ensure that certain themes were touched on. As an example, the participants were asked to comment on the 'threats' that the sites may be facing, if any, in place of a more leading questions directing the participants to identify the impacts of climate change that the sites are vulnerable too. These potential limitations were acknowledged when discerning themes from the interviews, and interview transcriptions were continually re-read to ensure that themes were representative of all participant responses. The following Chapter details the key findings that arose from the interviews while recognizing the potential limitations of this research.

4. RESULTS

This Chapter will describe the qualitative and quantitative analysis, derived from interview responses to the maps created with the RPAS. The maps themselves are displayed publicly on ArcGIS Online and can be reached via the links provided in Appendix IV. Semi-structured interviews (n=9) were undertaken with participants representing a variety of stakeholders; community members, local NGOs, academia and government representatives from planning and resource management. The interviews were undertaken to assess the visualization afforded by the RPAS maps (and therefore the ability to communicate the impacts of climate change), discuss limitations associated with utilizing RPAS, and gain insight into the potential or current coastal applications. All of which assist in investigating the suitability of RPAS as a tool to support climate change adaptation strategies. The results are organised by relevance to each of the three research questions, along with some additional responses of relevance to the project. The responses provided by the interview participants detailing limitations associated with the use of RPAS for coastal mapping, as well as the applications for these maps, are complimented by those derived from the literature review within Sections 4.2.2. and 4.3., respectively.

4.1. Research Question 1: *How can maps that use hyperspatial imagery affect people's perception of coastal vulnerability to sea level rise and other impacts of climate change?*

In order to investigate Research Question 1, the interview participants were asked to firstly describe any threats that the coastal sites may be vulnerable too, and then comment on their perception of the vulnerability of the wharf or beach to these threats. The questions were asked whilst the participants were viewing and manoeuvring a Google Maps™ image, then again when viewing and manoeuvring the maps created by Remotely Piloted Aircraft Systems (RPAS). In response to these questions, or when asked in what ways the RPAS maps influenced their opinion on coastal vulnerability to the impacts of climate change, the participants reacted in two ways, which became apparent from the content analysis. Viewing the RPAS imagery evoked emotional responses, but participants also identified physical characteristics that the RPAS maps display, leading the responses to be coded under these two themes.

4.1.1. Participant responses on the vulnerability of the sites to the impacts of climate change

From viewing the Google Maps™ imagery, all the threats that the participants identified as affecting the two sites were linked to climate change. These threats included sea level rise, storm surge, coastal erosion and inundation, and infrastructure damage. The responses given regarding the threats and relative vulnerability were based on the participants own perception, the knowledge of the impacts of climate change varied between participants with some demonstrating greater understanding of these impacts. To account for this bias and ensure representation, the participants included a variety of different stakeholders.

After viewing solely the Google Maps™ imagery, it was apparent that most of the participants were concerned about the vulnerability of the wharf (78%) and the beach (57%) to the impacts of climate change they had previously identified. After viewing the maps created by the RPAS, the participants did not speak to any threats other than those they had originally identified from the Google Maps™ imagery. Nonetheless, some of the participants' concerns pertaining to the vulnerability of the sites increased as a result of viewing the RPAS maps, 22% of participants were more concerned about the vulnerability of the wharf and 29% were more concerned about the vulnerability of the beach to the impacts of climate change. The remainder of the participants expressed that their opinion on the vulnerability of the sites had not changed after viewing the RPAS maps. However, some participants (22%) mentioned that had they not been familiar with the site, they believed that the RPAS maps would better inform them of the vulnerability of the site to the impacts of climate change. While the RPAS maps only elevated concerns in a few participants, most of the participants (56%) highlighted that the maps gave further evidence of or helped to clarify the impacts of climate change that they already suspected the site may be vulnerable to.

It was interesting to see how the concerns the participants expressed on the vulnerability of the sites to the impacts of climate change varied between the wharf and the beach. Two participants expressed little concern with the vulnerability of the beach to the impacts of climate change, even after viewing the RPAS map, as the site has no coastal infrastructure that could be damaged and no obvious impacts to people. One participant stated that the site consists of "recreational land so will have no negative impact on livelihood" (PN01), whilst another pointed out that "we all have to understand that the coast changes, and that change is perfectly normal" (PN09). There was greater concern with the vulnerability of the wharf to the impacts of climate change; with only one of the nine participants expressing no concern as to the vulnerability of the wharf after viewing the Google Maps™ and RPAS imagery. The participant in question showed greater interest in the RPAS imagery of the beach inside Thomas Raddall Provincial Park, a site they were previously familiar with. The RPAS map elevated their concerns on the vulnerability of the beach to the impacts of climate change, which gave further evidence to their suspicions that in the future there may be breaching into the lake behind the beach (Figure 4 displays 2D RPAS imagery depicting the beach and the lake behind). The RPAS map was able to convey information on the potential loss of the beach and other changes, as well as scale and distances between features, which will have management implications for the Park.

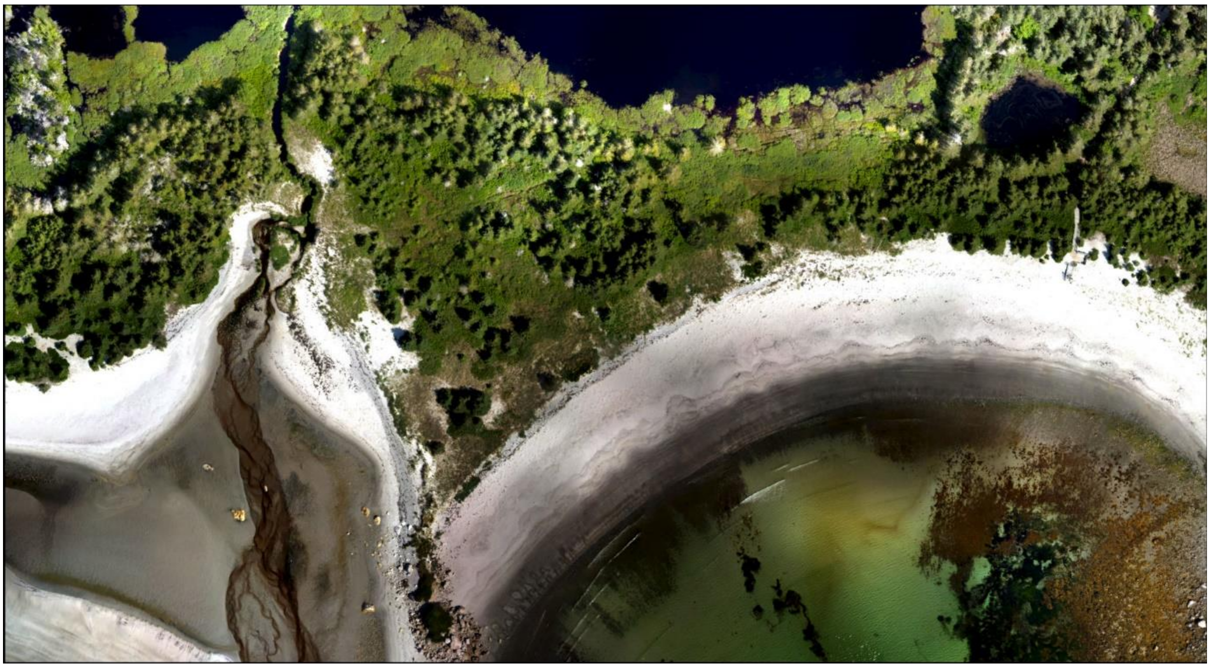

Figure 4 *– Screengrab from a 2D map of Thomas Raddall Provincial Park, created with the RPAS imagery.*

4.1.2. Emotional responses of participants after viewing the RPAS maps

After viewing the maps created by the RPAS, the interview participants had several positive emotional responses. Five codes were identified from the responses, displayed in Figure 5. All the participants responded positively to the RPAS maps, varying from amazement at the RPAS maps themselves, “isn’t that amazing what you can do” (PN01), to commenting on how the maps provide a “much stronger sense of place, almost feel like I can get into every nook and cranny” (PN05). The maps provide a 3D view of the sites at a much higher resolution, and one participant stated that “it definitely helps the perception of space being able to see it in the third dimension" (PN03), whilst another noted that: "(The RPAS) maps convey a lot more information that google maps, as good as it is, does not convey… do not see the overall holistic picture as much as you do here" (PN05). When asked, all the participants bar one expressed that they felt more connected to both sites after viewing the RPAS maps (89%). These sentiments not only reflect the quality of the visualisations that the RPAS maps offer, but also demonstrate that people's connection to certain places can be enhanced through the imagery, which in turn can increase awareness of the necessity to mitigate for certain hazards or engage in adaptation measures.

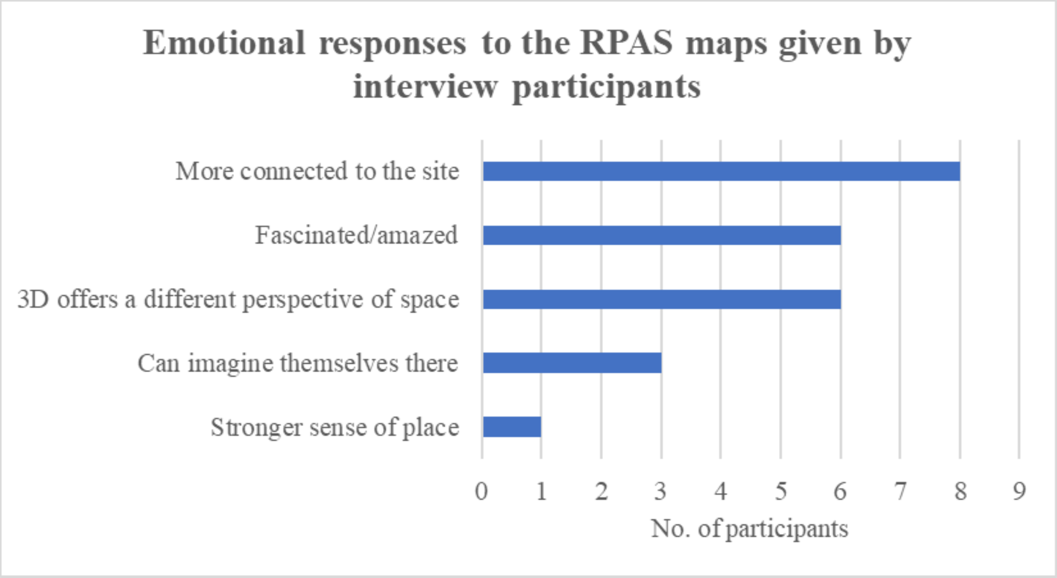

Figure 5 *– Graph depicting the coded emotional responses given by interview participants after viewing the RPAS maps.*

4.1.3. Physical features that the RPAS maps convey as identified by participants

The RPAS maps not only provide a high quality of visualisation of the sites, but also display physical features more clearly than Google Maps™. All the interview participants noted that the maps created by the RPAS convey more information than Google Maps™ imagery, and when giving their opinion on the vulnerability of the sites after viewing the maps created by the RPAS, many participants referenced specific physical features that the RPAS maps convey that helped them form their opinions. Figure 6 displays the physical features mentioned by the participants; the list of features is extensive and replicates those highlighted in current literature (Hansman & Ring, 2019). It is worth noting that many of the features depicted are time dependent (for example, only from imagery collected at low tide can the viewer identify low and high tide marks), therefore may vary in RPAS maps created using imagery collected on different occasions. Furthermore, the features vary in scale and some are only visible when the viewer adjusts the scale by enlarging the maps.

The ability of the RPAS maps to convey the listed features is what enables the observer to feel more connected to the sites after viewing the maps created by the RPAS, as well as providing more evidence on which to comment on the vulnerability of the sites to the impacts of climate change. Information on the physical landscape of the sites can be gained through identifying the type of sediment, exposed bedrock and vegetation present (in shallow water as well as on land), the terrain and shape of the coastline. For manmade features the maps convey materials and the structural composition, as well as their height (or elevation) relative to sea level. The high resolution, ability to view from oblique angles, various scales and from 2D and 3D perspectives, all assist the viewer in identifying these features and assessing vulnerabilities.

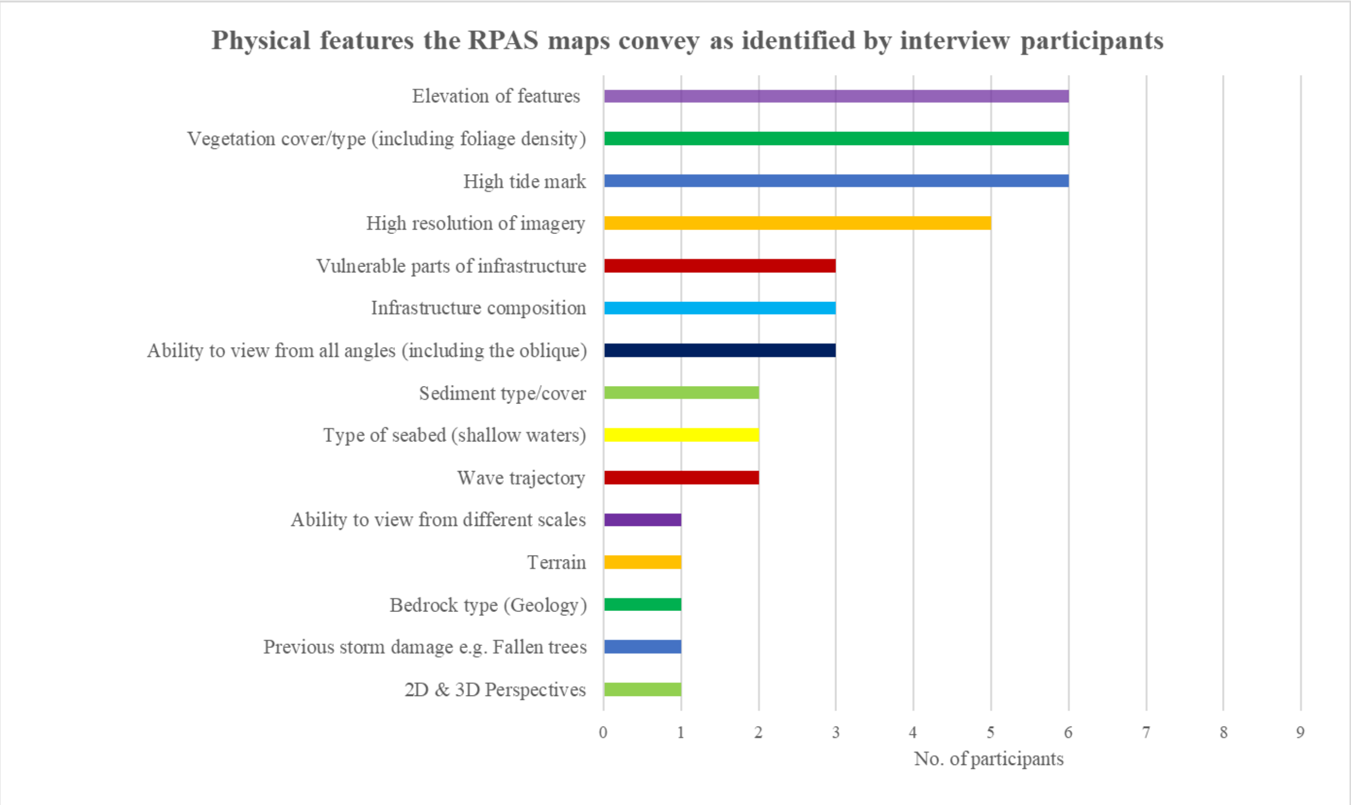

Figure 6 *– Graph depicting the physical features the RPAS maps convey, as identified by the interview participants.*

4.2. Research Question 2: What are the advantages and limitations of using RPAS to create coastal maps in Nova Scotia?

Before exploring potential applications for RPAS maps, it is worth considering the advantages and limitations of utilizing RPAS compared to other platforms, in order to gauge the suitability of the technology for coastal mapping. During the interviews, participants were asked identify advantages of using RPAS over planes or helicopters, as well as any issues or limitations that they could envision when using RPAS to create coastal maps.

4.2.1. Advantages when utilizing RPAS

Participants commented on a number of benefits, aside from the improved visualisations, that RPAS provide for coastal mapping, in comparison to using a plane or helicopter. Over half of the participants noted that RPAS are more cost effective (56%), and they were described by one participant as a "relatively low-cost alternative to flying airplanes" (PN07). 44% of participants remarked that RPAS are quicker to operate than an airplane or helicopter, one commented that "the time saving is unreal, much quicker than airplane data collection" (PN06). Participants also noted that using RPAS can provide improved data to that collected by an airplane or helicopter (44%), and that the data can be easily replicated (33%). RPAS store the data they collect, including the flight plan, so the exact same flight can be completed with relative ease. One interview participant that had previously used RPAS for work purposes stated that "We capture a lot more sites in a lot less time and for each site we're able to go back and take any measurement we want, so (using RPAS has) improved our science" (PN09).

4.2.2. Limitations when utilizing RPAS

On the flip side, working with RPAS poses its own set of limitations. The interview participants were asked to identify any observations they may have on working with RPAS to create coastal maps. The responses were coded, and the codes are displayed in Figure 7. Table 1 gives a description and an example from the literature for each limitation identified by the interview participants.

Almost all the limitations proposed by the interview participants were present in the literature, except for one (inaccessibility of the technology to small communities). None of the interview participants raised the issue of the relatively short flight time that RPAS offer, which was described by Hardin et al., (2019) as the primary challenge for environmental remote sensing, or the lengthy processing time required for the software to generate 3D maps. The short flight time is due to the necessity to recharge the lithium polymer batteries, which while noted in the literature as being a major technical limitation shortening aerial extents, may not be known to those who have not operated RPAS, which was the case for most of the interview participants. Chapter 5 goes on to discuss the implications of the limitations listed here for creating coastal maps with RPAS.

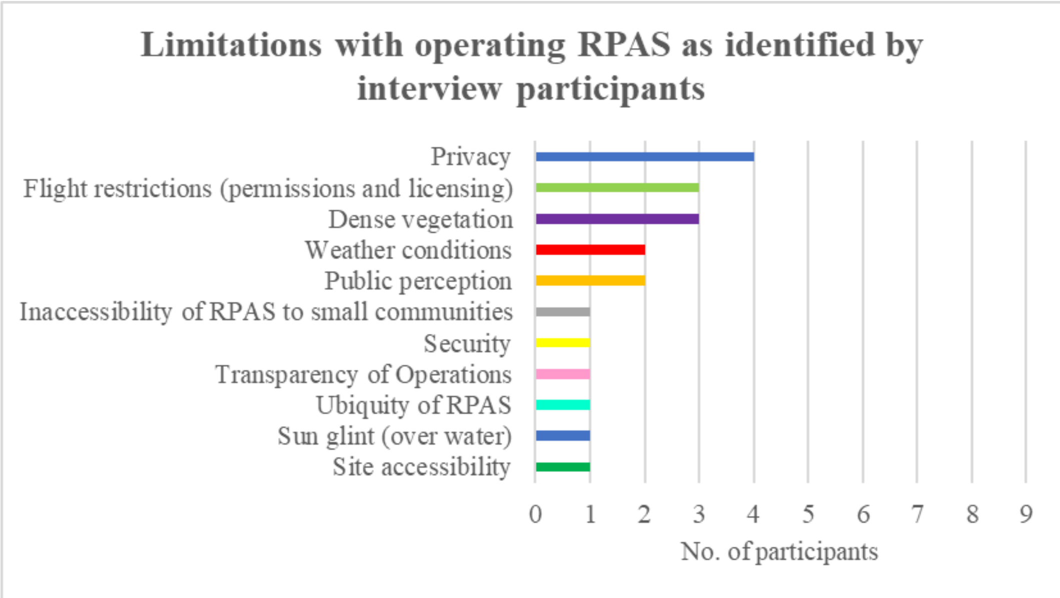

Figure 7 *– Graph depicting the limitations with operating RPAS, as identified by interview participants.*

Table 1 *– Depicts the limitations with utilizing RPAS for coastal mapping, as identified by interview participants, with an explanation and example from the literature.*

Limitation	Explanation	Examples from the Literature
Privacy	Property owners and bystanders must be notified of RPAS operations, to avoid any invasion of privacy.	Duffy et al., (2017).
Flight restrictions (permissions and licensing)	Operations must by law adhere to air transport regulations (no-flight areas, height and distance restrictions), hold RPAS pilot and registration licences and obtain access permission from all property owners. Additionally, the majority of RPAS models cannot fly directly over bystanders.	Milas et al., (2018), Transport Canada (2019).

Dense vegetation	The RPAS imagery cannot penetrate dense vegetation; therefore, topography and other site features will have less accuracy where vegetation is dense.	Varela et al., (2018).
Weather conditions	Adverse weather conditions can make it challenging to operate RPAS.	Duffy et al., (2017), Varela et al., (2018), Hardin et al., (2019).
Public perception	Without a social licence RPAS operations may encounter challenges.	Duffy et al., (2017).
Inaccessibility of RPAS to small communities	Whilst RPAS are much cheaper than planes or helicopters, accurately and safely operating the technology is still a challenge to many stakeholders (See Chapter 5.2).	
Security	For security reasons, coastal property owners may have restrictions on, and should be informed of the use of, the RPAS imagery.	Sandbrook (2015), Duffy et al., (2017).
Transparency of Operations	Ensuring that the operations are transparent throughout – to improve repeatability and minimize negative connotations associated with RPAS use.	Duffy et al., (2017), Rees et al., (2018).
Ubiquity of RPAS	The accessibility of RPAS (relatively low cost) and a lack of clear methodology or third-party verification for RPAS data, could lead to validity issues with some of the data that is being collected.	Rees et al., (2018).
Sun glint	Reflection of the sun from the surface of the water, or mud flats, can distort RPAS imagery.	Joyce et al., (2018), van Proosdij, pers coms, (2019).
Site accessibility	Physicality of accessing the site as the operator must always be in eyesight of the RPAS.	Duffy et al., (2017), Hansman & Ring (2019), Santangelo et al., (2019).

4.3. Research Question 3: *What are the potential applications of these maps for coastal communities in Nova Scotia to complement current climate change adaptation strategies?*

The greater detail of physical features that the RPAS maps provide, as well as the high-quality visualisations that enable observers to feel more connected to the sites, open the door for a wealth of potential marine and coastal applications. The current literature identifies many of these applications, as discussed in Chapter 2. However, as RPAS technology develops further and becomes increasingly affordable, there are likely to be other potential uses that are worth investigating. During the interviews, participants were asked to comment on either potential applications for the maps created by RPAS, or applications that are currently being utilized. Table 2 displays all the applications suggested by the interview participants, which were grouped into themes (Identification & Assessment, Prediction, Monitoring and Communication). The applications are listed alongside the relevant stakeholders, with an example (if available) of the application's effective use in Nova Scotia or elsewhere. Several applications suggested by interview participants are not at this stage supported by examples from the current literature or from desktop research, but it is possible that they are being explored.

Table 2 *– Depicts the current and potential applications for RPAS coastal maps, identified by interview participants.*

Theme	Application	Stakeholders	Examples from the Literature
Identification & Assessment	Identify infrastructure vulnerable to damage from storm surge or sea level rise.	All levels of government, community groups, coastal property owners, coastal contractors.	Nova Scotia Department of Agriculture (C. Ross. pers coms, 2019).
	Assess recent storm damage.	Provincial and municipal government, academia, community groups.	Carried out by UPEI Climate Lab following Hurricane Dorian (Steepe, 2019).
	Map habitats for SAR & assess anthropogenic impacts (current and potential).	Biologists, academia, NGOs, community groups.	Vulnerability of turtle nesting habitat in the Mediterranean (Varela et al., 2018).
	Analysis sites to gauge potential coastal restoration.	Provincial and municipal government, coastal contractors, academia, NGOs, community groups.	Re-establishing salt marshes (restoration of coastal wetlands) in NS (van Proosdij, pers coms, 2019).
	Assess risk to new coastal developments (Infrastructure and private property).	Coastal contractors, real estate agents, mortgage brokers.	Commercial RPAS Operation Professionals such as AeroVision Canada (AeroVision Canada, 2019).
	Determine coastal setbacks.	Coastal property owners or developers, bylaw enforcement.	

Prediction	Display projected sea level rise.	All levels of government, coastal property owners, community groups, academia, general public.	Vulnerability of turtle nesting habitat in the Mediterranean (Varela et al., 2018).
	Model fine-scale flood risk (site-specific).	Provincial and municipal government, coastal property owners, community groups, academia, general public.	To assess the flooding that may occur from dyke realignment in the Bay of Fundy (van Proosdij, pers coms, 2019).
Monitoring	Capture storm tides.	Municipal government, coastal property owners.	
	Monitor the effectiveness of revegetating shorelines and other coastal restoration efforts.	Coastal contractors, academia, coastal property owners, community groups, local government.	Post-restoration monitoring of salt marsh restoration projects (Bowron et al., 2015).
	Monitor and model coastal erosion.	Local government, community groups, coastal property owners and developers.	Nova Scotia Department of Energy and Mines.
	Bylaw enforcement.	All levels of government.	Monitoring MPAs against illegal vessels (Arefin, 2018).
	Management of protected coastal areas (including Provincial Parks).	All levels of government, academia, NGOs, community groups.	
Communication	Participatory mapping.	All levels of government, academia, NGOs.	Utilizing RPAS for grassroots innovation in Central America (Panque-Gálvez et al., 2017).
	Inform tourists.	Provincial and municipal government, NGOs, community groups, general public.	

4.4. Additional interview responses

Due to the semi-structured nature of the interviews, there were comments or responses of relevance to the project that did not fall under any of the three research questions. The majority of the participants (67%) were aware that drones could be used to create maps such as the ones displayed, prior to our interview. However, few had seen maps created by RPAS before, so the interviews provided an opportunity for the participants to view and engage with the maps. One such participant remarked that: “(I) have heard a lot about them but haven’t seen a lot of images - didn’t realise how much clearer and better the images would be to the google maps” (PN04). Whilst the findings may have varied if the participants had more knowledge on RPAS and the maps they can be used to create, the participants were chosen to ensure a variety of stakeholders were represented, not limited to those with expertise in the field.

To summarise their opinion on the maps created by the RPAS, the participants were asked if they saw value in using RPAS to create more fine-scale maps of coastal infrastructure and ecosystems in Nova Scotia. All of the participants confirmed that they do see value in creating more maps, most participants (78%) answered that a variety of coastal regions would be useful to map using RPAS imagery – natural as well as built environments. Overall, the interview participants were supportive of the RPAS maps. Although this research project involved a small sample size of participants, their support for further RPAS operations and their enthusiasm when suggesting potential applications, is indicative of the potential benefits RPAS may provide for coastal Nova Scotia. While acknowledging the current limitations and recognising the fine-scale on which RPAS operate, the detailed site level imagery they produce can support adaptation strategies and decision-making through identifying, predicting, monitoring and communicating the impacts of climate change.

5. DISCUSSION

5.1. Utilizing RPAS to communicate Climate Change

RPAS have the potential to increase awareness to the impacts of coastal climate change, through the high-quality and detailed hyperspatial imagery they collect. The images can be used to create maps that provide a holistic view of the vulnerability of the sites - this became apparent through the stakeholder interviews conducted for the project. The maps do this through providing high quality visualizations, which prompt viewers to feel more connected to the site as they can picture themselves there. Furthermore, RPAS can fly at low altitude collecting imagery at a high resolution, not just from a bird's eye view but also from oblique angles. The oblique view enables features to be seen from different angles, for example, a cliff face that may be subject to erosion. The imagery conveys detailed physical characteristics of the sites, be them natural or built landscapes. As summarized by one interview participant: "The maps created by the RPAS display a breadth and depth of physical features, which enables a more holistic picture of the site" (PN05). The interactive maps that they can then create provide 2D and 3D perspectives, at different scales, as the viewer can zoom in closely on particular features. As an example, from viewing the RPAS map of the Port Mouton Central Breakwater, the elevation of the wharf above the high and low tide marks can be gauged, which enables the viewer to picture the wave height required to overtop the wharf.

In order to communicate climate change, reframe perceptions and foster social change, there are several recommendations in the literature; to provide understandable, scientifically accurate information, to generate novel and vivid imagery to attract and hold viewers' attention, and to contextualize climate change impacts at the local and regional level allowing people to more easily imagine the impacts (Sheppard, 2012). By localising, spatialising and visualising, climate change implications can be successful in raising community awareness and expressing holistic community options for local level mitigation and adaptation (Sheppard et al., 2008). Visualisation theory suggests that the use of visualisations and visioning processes by landscape architects is imperative in communicating climate change, by 'making climate change personal' providing the public with realistic views of familiar landscape under future scenarios (Sheppard et al., 2008). RPAS collect high-resolution imagery providing detailed visualisations - a 2012 study investigating different sea level rise visualisation techniques on planners and politicians in the Halifax Regional Municipality found that representations that seemed real, such as photo simulations, were often ranked higher than other visualisations (Maher et al., 2012).

Maps created by RPAS provide novel and vivid imagery for sites at a local level, as shown in the emotional responses given by interview participants to the RPAS maps created for this study. The vivid imagery, coupled with scientifically robust information, have the potential to act as a useful tool for communicating the impacts of climate change, in turn contributing to adaptation - raising awareness of local climate change consequences supports informed community dialogue and decision-making (Sheppard et al., 2008). For the interviews conducted in this project, the participants were not informed of any of the impacts of climate change that the sites mapped with the RPAS could be at risk of; instead, they guessed the impacts based on the visualizations and their own knowledge. The maps could be enhanced with other data explaining some of the changes that will be expected to occur with climate change. Using RPAS maps in this manner could be of use to a host of different stakeholders, community groups, academia, non-governmental organizations and all levels of government. For instance, RPAS maps of vulnerable coastal sites that are popular with tourists could be used to inform visitors of the impacts of climate change the site is facing, to create support for the area and to spark social change. Local governments and community groups may see the greatest benefit from this application, as these visualizations can help not only educate the public, but for both decision making to mitigate climate change and for monitoring environmental processes.

Utilizing RPAS to create coastal maps can support community-led adaptation, as well as government led initiatives. Participatory mapping is the creation of maps by local communities, often supported by governments, non-governmental organizations and universities (IFAD, 2009). Social participation is an important mechanism to find lasting and sustainable solutions to environmental issues, and studies have found that 3D participatory modelling has helped to improve the capacity of communities to interact with the relevant institutions and influence resource allocation and management (Di Gessa, 2008). The high-quality imagery RPAS collected can assist with 3D participatory modelling, and as such the use of the technology as a focal point for participatory mapping is worth exploring. As an example for the Port Mouton Bay region, the RPAS imagery could have assisted with the Oceans Canada initiative that encouraged community members to map climate change impacts they are already observing in the region (OceanCanada, 2019). In addition, Panque-

Gálvez et al., (2017) suggest that the progressive adoption of RPAS by indigenous peoples may trigger grassroots innovations that will promote greater environmental justice and sustainability. The maps created by RPAS can support local communities land rights, and when operated by local activists, can contribute to an empowering process of self-emancipation (Radjawali & Pye, 2017).

5.2. The current feasibility of RPAS operations

The potential for RPAS to support and empower local communities comes in part from their ability to provide a cheaper and easier method for collecting hyperspatial imagery, when compared to that obtained via airplane or helicopter. The RPAS flights for this project took some preparation, requiring an initial RPAS purchase as well as the purchase of spare batteries and processing software; however, the costs are a fraction of those required for collecting the same imagery from other aircrafts. After the initial investments the operational costs are low, especially when combined with the ability of RPAS to store flight paths, which ensures that flights can be quickly and easily replicated. However, whilst there are clear benefits to utilizing RPAS for coastal mapping, there are also limitations that should be acknowledged – not all stakeholders have the capacity to fully utilize RPAS, the current regulatory framework poses some challenges, and there are technical limitations with the present form of the technology.

In order to increase the current capacity to operate RPAS, organizations must make initial investments in the equipment and training. The RPAS operator must pass pilot certifications (Transport Canada, 2019a), the training for which can be challenging and time consuming. Once purchased, a framework or methodology for collecting and processing the data should be established, to ensure operational transparency and to enable the data collection to be easily replicated. The initial costs, paired with the necessity for the safe and accurate operation of RPAS, can make the technology still inaccessible to small communities and other stakeholders. One interview participant, who is employed by a small-town municipality, commented on how local decision makers could greatly benefit from RPAS maps. However, it is “hard for a small municipality/rural region to keep up, would love to have info like this but do not necessarily have the resources” (PN07).

Aside from the starting costs and initial time commitment required for RPAS operations, there are other limitations that must be considered and currently can make RPAS unsuitable for certain applications. As the RPAS industry expands, regulations surrounding their use must also develop, although this has not always happened in tandem. These regulations are crucial to enforce limits in invasion of privacy, protecting bystanders and the rights of coastal property owners, and ensuring public safety. In the UK, flights have been suspended on several occasions from major airports due to the presence of unauthorized RPAS in the vicinity, most recently halting all flights out of Gatwick Airport for three day in December 2018 (Topham et al., 2018), as airborne collision poses a serious risk to the safety of an aircraft. Some RPAS have the ability to transport objects, which unregulated poses a large risk to public safety. Additionally, if RPAS suffer a malfunction in the air, which is a greater risk in colder climates as batteries can cease to operate below a particular threshold (van Proosdij, personal communication, 2019), the falling debris is hugely dangerous to any bystanders. This is a very real concern when operating RPAS in Nova Scotia, where there are large seasonal variations in temperature.

For the reasons listed above, RPAS models in Canada must hold RPAS Safety Assurance, declared by the manufacturer, in order to be used for advanced operations (Transport Canada, 2019c). "Advanced operations" pose a higher risk to people and aircraft, and they include operating within controlled airspace, near people (within 30m) or over people. For current operations in Nova Scotia, DJI is the most popular supplier of RPAS (Lapierre, personal communication, 2019), and DJI products cannot fly directly over or within 5 metres of any persons not associated with the operation (Transport Canada, 2019c). With the regulations effective from June 1st, 2019, operators must also by law adhere to air transport regulations and hold RPAS pilot and registration licenses (Transport Canada, 2019a). These regulations are essential for public safety, but also provide a strong regulatory framework to support the continued growth of RPAS operations. Whilst careful pre-flight planning can overcome most of the challenges that the regulations may at first present, such as requiring permission to access property, the inability to fly over bystanders can limit RPAS usage. Perhaps most disadvantageously, without advanced pilot certifications and RPAS models cleared for all advanced operations (Transport Canada, 2019c), RPAS cannot fly over roads, and will also encounter difficulties over busy coastal destinations (e.g. over popular public beaches). Another potential application that is limited under the current Canadian regulatory framework is the use of RPAS for bylaw enforcement, such as monitoring MPAs against illegal vessels (Arefin, 2018). Utilizing RPAS in this way could potentially breach current regulations, if they were to fly over bystanders not associated with the RPAS operation.

As discussed in Chapter 2, adverse weather conditions and hard to access sites can pose operational challenges with RPAS flights, for example, in the Bay of Fundy tide times must be observed to ensure safe site access. Moving features and sun glint from the surface of water can also distort the imagery that the RPAS collect (Joyce et al., 2018). The ability of RPAS to operate at low altitudes enables them to collect high resolution imagery, but it also restricts the size of the flight area. Additionally, the short battery life considerably limits flight time available, which makes RPAS operations more suitable for short coastal stretches. Where accurate topographical or bathymetry data is required and there is a dense canopy layer, LiDAR is preferred over imagery collected from an RGB camera due to its ability to pierce through vegetation and more accurately map topography. The most commonly used platforms for acquiring LiDAR data are airplanes and helicopters (NOAA, 2018). Collecting LiDAR from an aircraft provides data for a much larger geographic region, so the data is more suitable for analysis on a larger scale, such as for the entire Province of Nova Scotia. While the Applied Geomatics Research Group (AGRG) work extensively with RPAS in Nova Scotia, they generally use topo-bathymetric LiDAR for coastal flooding applications, as it is able to cover much larger areas with a higher accuracy in the z dimension (N. Crowell, personal communication, 2019).

The limitations identified above reinforce the idea that RPAS should not be seen as the only technology to be used for collecting remote sensing data, but rather as one tool within a toolbox. For fine-scale coastal sites, under favorable weather conditions and with low vegetative cover, RPAS offer an appropriate and often preferable option to other forms of hyperspatial data collection. Once all necessary licenses have been obtained, and ensuring that thorough pre-flight planning is undertaken for each flight, RPAS offer a cost-effective tool that can be used to frequently collect detailed snapshots of sites.

5.3. RPAS as a tool to assist Coastal Management

Using RPAS to create coastal maps should be considered one tool that can assist with climate change adaptation, in the context of broader strategies for adaptation. RPAS have the potential to not only communicate more vividly coastal impacts of climate change, but to assist with other management decisions. Recognizing that there are some limitations to current RPAS operations, this section discusses current and potential uses for RPAS in Nova Scotia, to provide support for adaptation strategies and decision-making through identification and assessment of hazards, assisting in the prediction of future threats, and monitoring coastal changes.

In Atlantic Canada, asides from recreational and commercial photography and cinematography, several applications for RPAS imagery are already being utilized. The University of Prince Edward Island Climate Lab used RPAS to capture and assess the damage in the wake of Hurricane Dorian (Steepe, 2019). As the intensity and frequency of storms increases, RPAS may present an opportunity to document storm damage in coastal Nova Scotia. This information can be of use to multiple sectors, whether it be for academic research as in PEI, municipal and provincial governments identifying damaged infrastructure or hazardous sites, or for damage to private property.

For man-made infrastructure, such as wharfs, roads, bridges, causeways and other structures built in proximity to the coast, the maps that RPAS create can offer several uses. In addition to assessing recent storm damage, they can identify infrastructure vulnerable to damage from storm surge or sea level rise. For the Central Port Mouton Breakwater, one of the interview participants who was familiar with the wharf was able to point out a section where previously storm surge had overtopped the breakwater. Once pointed out, the weaker section could be seen quite clearly, demonstrating the potential for the map created with the RPAS to remotely communicate vulnerable sections of the wharf to the relevant government department (the Small Craft Harbours division of DFO). Maps such as these may be useful to community harbour authorities to present vulnerabilities with infrastructure to the government, and for engineering firms to inform repairs and rebuilding.

RPAS maps can also aid in assessing risk to proposed coastal developments, be it on private property or public infrastructure. The detailed maps provide snapshots of coastal sites, to assist with site assessments that can be of use to a variety of stakeholders, including coastal contractors, potential and current property owners, real estate agents and mortgage brokers. Utilizing RPAS for site assessments is becoming more common place amongst engineering firms (an example of a commercial RPAS operation professional operating in Nova Scotia is AeroVision Canada). In addition to providing detailed imagery of sites, RPAS may be of assistance to the new Nova Scotia Coastal Protection Act. Regulations for the Act are in the process of being drafted, which will determine coastal setbacks as well as important ecosystems to be protected from development. Setbacks could be quantified on the RPAS maps and incorporated into planning for coastal property owners or developers.

The detailed snapshots of sites, that can be viewed and measured remotely, are a major benefit of the RPAS maps. Besides engineers, other organisations can use the maps for site assessments where the impacts of climate change on vulnerable areas are mitigated through soft engineering approaches, such as coastal restoration. One interview participant, a restoration practitioner, spoke about how RPAS could assist them with revegetating coastal areas, to stabilise banks, help prevent coastal erosion and provide a nature-based solution to flooding. For this type of work, the RPAS maps offer potential for improved site assessments to determine the type and quantity of vegetation required, as well as consistent monitoring and evaluation of the revegetation's effectiveness.

For natural environments, the detailed physical characteristics that the RPAS imagery conveys enables the viewer to distinguish changes in vegetation and sediment. This can help viewers identify habitats for species at risk. The maps can identify anthropogenic encroachment onto these habitats, which could aid with ecological impact assessments for new developments. RPAS have been used to these effects in several scientific studies. Varela et al., (2018) used RPAS to identify and map turtle nesting habitats in the Mediterranean and assess how projected sea level rise may impact these habitats. An example in Nova Scotia is the endangered shorebird, the Piping Plover, of which there are only 40 breeding pairs left in the wild (Bird Studies Canada, 2018). The beach within Thomas Raddall Provincial Park captured for this project presents suitable habitat for the Piping Plover, and as such mapping habitats with RPAS may be beneficial for bird conservation groups, such as Bird Studies Canada.

The study by Varela et al., (2018) overlaid projected sea level rise onto the maps created by the RPAS. This application in itself poses a useful tool to coastal Nova Scotia, due to the high levels of sea level rise predicted over the next century (Richards & Daigle, 2011). As mentioned previously, RPAS mapping is unsuitable for modelling province-wide sea level rise. However, RPAS offer detailed site level mapping, that can display projected sea level rise on a more localized scale. In fact, the Friends of Port Mouton Bay Asset Map, which relied heavily on input from community members, highlighted the necessity of a 1 metre contour sea level rise elevation line to be overlaid along the Port Mouton Bay, to inform and prepare the local community (Ross, 2018). Coastal maps created with RPAS can provide basemaps to overlay not only sea level rise projections, but also flood models. Capturing flood extents can also calibrate or validate hydraulic models, fluvial as well as marine. The team at Saint Mary University have been utilizing RPAS maps to this extent for the dyke management and realignment work in the Bay of Fundy. By flood modelling the site, the team can estimate the restoration potential decommissioning a dyke may afford (van Proosdij, personal communication, 2019). Using RPAS in this manner for modelling localized flood risk, or potential sea level rise, can greatly assist government at the municipal, provincial and federal level.

Compared with other methods for obtaining aerial imagery, revisiting sites with RPAS is made relatively straightforward by their ability to store flight paths, increasing the scientific validity when capturing changes over time. For coastal restoration efforts, RPAS can be used to monitor the effectiveness and capture a distinct snapshot in time, when replicated any changes between RPAS maps can be observed. For the climate resiliency work undertaken in the Bay of Fundy, RPAS are being used to monitor the effectiveness of restored saltmarshes (van Proosdij, personal communication, 2019). The Province is already utilizing RPAS to determine rates of coastal erosion and monitor changes over time for several coastal sites. Monitoring and modelling coastal erosion are important for predicting future changes to the coast, which will likely be exacerbated by climate change.

Supplementary to assessing, predicting and monitoring changes to the coast, the detailed snapshots that RPAS provide can have other management implications; as suggested by one interview participant, the maps can provide support for land-use planning. As an example, they can guide decisions in public spaces on which paths need restoring and where funds should be spent. The applications described here are a selection of examples as to how RPAS could assist with coastal management. To reiterate, RPAS are just one tool that should be further explored in order to enhance coastal adaptation to climate change, and it is important to acknowledge the limitations that come with their usage.

6. RECOMMENDATIONS & CONCLUSIONS

As the use of RPAS continues to grow worldwide, their increasing accessibility will open the door for the applications discussed in Chapter 5. It is worth noting that while this research is tailored towards use of RPAS in Nova Scotia, most conclusions and observations are applicable elsewhere, bearing in mind differing environmental, economic and political conditions, and the regulatory frameworks that exist under different contexts. While the initial investment and the training to obtain RPAS pilot licenses can be challenging, the long-term benefits are substantial. For fine-scale coastal sites, RPAS undoubtably offer a cost-effective, relatively quick and easy method of collecting remote sensing data, that has the potential to support climate change adaptation strategies.

6.1. Recommendations

Encouraging the use of RPAS for current projects, including nature-based solutions such as saltmarsh restoration thereby absorbing sea level rise and storm surge, will help increase regional capacity for climate change adaptation. Current innovative uses discussed in Chapter 2.7. pave the way for the use of RPAS in future research and management measures in Nova Scotia. These applications are already being successfully implemented. Therefore, supporting and expanding the current uses for RPAS will solidify their position as a valuable tool to assist with adaptation strategies.

Coastal maps created by RPAS have a suite of potential applications that can enhance the toolbox and assist communities with adaptation. The RPAS maps offer improved visualizations of climate change impacts, and can provide data identifying, assessing and monitoring these impacts, as well as predicting future changes. These services provide information on which to base management decisions and support adaptation measures and policies. Using RPAS for these applications can be of value to a variety of stakeholders, including private property owners, community groups, NGOs, academia, municipal, provincial and federal governments. In the current context, there are of course other complexities that may make some of the suggested applications unsuitable to different stakeholders, such as financial and human capacity and complex regulatory frameworks. However, there are many uses worth exploring in which coastal maps created by RPAS can function as a tool to assist with increasing Nova Scotia’s capacity to adapt to climate change. Given the opportunities discussed here that imagery of this caliber can present for climate change adaptation, it seems prudent to continue to explore and utilize RPAS as a more affordable option for fine-scale hyperspatial data collection.

In order to support the increased use of RPAS as a tool to assist with coastal climate change adaptation, the current lack of easily available methodology detailing RPAS data collection procedures (including pre-flight planning) should be addressed. Their ease of access combined with the lack of third-party verification for RPAS data, can at times threaten the validity of data collected. Developing and sharing clear methodologies for RPAS will improve accuracy with data collection and provide support for new operators, increasing the ease of access to the technology and encouraging new use. This would also increase transparency with operations, improve safety, and enhance the repeatability of data collection. In addition, increased transparency can improve public perceptions of RPAS. To minimize the negative connotations that sometimes surround RPAS, increased public exposure to the positive uses of RPAS could help to create familiarity with the technology and the benefits they provide, aiding the integration of the technology into current management practices.

In summary, this research highlighted three key recommendations to support the use of RPAS as a tool to assist with coastal climate change adaptation in Nova Scotia. The current applications and uses should be encouraged and expanded in order to increase regional resilience and adaptation capacity; other potential applications should continue to be explored; and transparent operational procedures should be developed in ensure safe and accurate data collection.

6.2. Conclusions

Nova Scotia’s low elevation coastline is particularly vulnerable to the impacts of human-induced climate change, including sea level rise and more frequent, intense storms. With time these impacts will likely be exacerbated, so exploring cost-effective adaptation measures is of the utmost importance. The necessity for climate change adaptation is just as critical for small rural areas, although currently there is more readily available hyperspatial data for larger urban areas, such as Halifax (Geomatics Association of Nova Scotia, 2019). To address this, RPAS offer a relatively low-cost alternative to aircrafts for collecting remotely sensed data at a small spatial scale. The major benefits of RPAS over other forms of hyperspatial imagery collection are the price, the relatively ease of operation and therefore the repeatability of data collection (Green et al., 2019). Their size and manoeuvrability mean that they can collect low altitude data providing high resolution imagery. As the uses for RPAS continue to expand, exploring the potential benefits that the technology can provide for marine and coastal management should be a priority.

This research has demonstrated how RPAS can act as a tool to assist with climate change adaptation for coastal communities. The maps that they create can alter public perceptions of the risks posed by climate change through the high-quality visualizations. These visualisations are imperative to communicating the impacts of climate change (Sheppard et al., 2008), as well as providing support for management decisions and adaptation measures and policies. The high level of detail the maps created by RPAS afford enables viewers to gauge several physical characteristics, providing a more holistic perspective of the coastal environment and lending the maps to a host of potential applications. These include using maps created by RPAS to model projected sea level rise and flood risk along the coast, as well as identifying vulnerable coastal infrastructure and areas of risk for new developments. Once at-risk areas are identified, RPAS can help communities find ways to adapt; one way of mitigating the impacts on these vulnerable areas is through “soft engineering”, such as coastal restoration. The ability of RPAS to create detailed fine-scale coastal maps is already being explored in Nova Scotia; the Province is monitoring coastal erosion and RPAS are being used to assist with the management of dykes in the Bay of Fundy (van Proosdij, personal communication, 2019). The RPAS maps can be used to quantify the impacts and support management decisions moving forward, such as identifying infrastructure to be reinforced, whether coastal developments are advised etc. With the continued increase in accessibility of RPAS, the momentum may provide an opportunity for RPAS being used increasingly as a tool to assist with climate change adaptation measures.

It should be recognized that using RPAS for coastal mapping does have its limitations; they are only suitable for fine-scale mapping; bad weather and site access can impede flights; and the current Transport Canada regulations cause some flight restrictions, most notably regarding operations over bystanders. By undertaking thorough pre-flight planning and tailoring the use of RPAS to suitable sites and applications, RPAS can be utilised efficiently and to increasing extents. Clear methodologies should be developed in tandem with increased RPAS usage, and made available to RPAS operators, to improve operational capacity and increase transparency. Given the rate at which the impacts of climate change are being observed, it seems prudent to continue exploring the uses of RPAS. Affordable, easy to operate, and able to produce detailed maps, RPAS have great potential as a tool to assist coastal communities as they adapt to a changing climate.

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APPENDIX I: SITE SHORTLIST

Site:	Rationale:	Location:
The Cove, Thomas Raddall Provincial Park	This area represents coastal ecosystems unique to the region, with little visible human impacts. It lies within a Provincial Park and conservation land and has been the focus of previous climate change studies.	 https://www.google.com/maps/@43.8270034,-64.8843401,1847m/data=!3m1!1e3
St Catherine's River Road	This area includes unique coastal ecosystems found in the region including salt marsh. It lies between the coast and St Catherine's River Road which has been identified as vulnerable to SLR in the Queens MCAP.	 https://www.google.com/maps/@43.8664515,-64.8752386,1738m/data=!3m1!1e3
Carters Beach	A pending protected area and a large sand beach – significant habitat for species at risk in Nova Scotia. This area was identified as a community asset by the Friends of Port Mouton Bay.	 https://www.google.com/maps/@43.9079218,-64.8171426,871m/data=!3m1!1e3

Summerville Beach Provincial Park	A protected area representing both sandy beach and an estuary, the trestle bridge as well as the provincial park were identified as community assets.	 https://www.google.com/maps/@43.9476326,-64.8234548,435m/data=!3m1!1e3
Hunts Point Wharf	A community asset identified by the Friends of Port Mouton Bay, 15 – 20 boats operate from this wharf. Hunts Point is listed as vulnerable to SLR in the Queens MCAP.	 https://www.google.com/maps/@43.952165,-64.7682046,440m/data=!3m1!1e3
Port Mouton Bay Wharf	Listed as a community asset by the Friends of Port Mouton Bay - a gathering place, boat launch and site for recreational fishing.	 https://www.google.com/maps/@43.9202756,-64.8406921,993m/data=!3m1!1e3

APPENDIX II: NORMAL CHECKLIST

SITE ASSESSMENT / PREPARATION			
Site Arrival Time	*Record*	▪ First Aid Kit	*Available*
Signage	*Posted*	▪ Sand Bag	*Available*
Site Inspection	*Complete*	Communications	
Control Station Set-up		▪ GRMS	*On & Clear*
▪ Documents	*Available*	▪ VHF Frequency	*On & Clear*
▪ Fire Extinguisher	*Charged*	Notify Property Owner	*Check*
PRE-FLIGHT			
Aircraft/Battery Log	*Record*	▪ Crew Licences / ID	*Available*
Documents		▪ Insurance	*Available*
▪ QRH	*Available*	▪ Log Book	*Available*
▪ Aircraft Manual	*Available*	Weather Brief	*Obtain*
▪ SFOC (Appl. / Approval)	*Available*	ATC Coordination	*Complete*
CREW BRIEFING			
IMSAFE	*Complete*	Site Orientation	*Brief*
Roles / Responsibilities	*Advise*	▪ Planned vs. Actual	
Flight Plan	*Brief*	▪ Launch / Crew Positions	
▪ Route		Communications	*Brief*
▪ Mode (Auto / Manual)		▪ Challenge / Response	
▪ Altitude		▪ Cell Phones	
▪ Total Time		Emergency Procedures	*Brief*
▪ Control Station Location		▪ Pilot Incapacitation (RTH)	
▪ Emergency Equipment		▪ Flyaway	
PRE-START			
Flight Plan	*Review*	▪ Camera	*Secure*
▪ Waypoints		▪ Props	*Secure*
▪ Altitudes		▪ MicroSD Card	*Inserted*
▪ Planned Time		▪ Link Switch	*RC*
▪ RTH Altitude		Controller Battery	*Charged*
Inspect Aircraft	*No Damage*	Flight Mode Switch	*P-Mode*
Assemble Aircraft		Mobile Device	*Charged*
▪ Batteries	*Secure*	Position Aircraft	*Launch Point*
▪ Aircraft to Landing Mode	*Check*	Crews	*To Positions*
START			
Controller Power	*ON*	Visual Calibration	*If Required*
Mobile Device	*ON*	GPS Signal	*Initiate*
Aircraft Power	*ON*	RC Signal	*Complete*
GS App	*Open*	Gimbal	*Activate*
Aircraft	*Connected*	RTH Position	*SET*
Firmware Update	*If Required*	Launch Point Area	*Clear*
GS App Update	*If Required*	“STARTING”	*ANNOUNCE*
Compass Calibration	*If Required*	Start Sequence	*Initiate*
TAKE OFF			
Motors	*Idle*	Launch Sequence	*Initiate*
Aircraft Status Indicators	*Green*	Flight Control Check	*Complete*
Launch Point Area	*Clear*	Start Mission	*Activate*
“LAUNCHING”	*Announce*		
LANDING			
“AIRCRAFT RETURNING”	*Announce*	“LANDING”	*ANNOUNCE*
Landing Point Area	*Clear*		
POST-FLIGHT			
Inspect Aircraft	*No Damage*	▪ Aircraft to Travel Mode	*Check*
Disassemble Aircraft		▪ Batteries	*Secure*
▪ Props	*Secure*	▪ Flight Log	*Complete*
▪ Camera	*Secure*	▪ Crew Debrief	*Brief*

APPENDIX III: INTERVIEW SCRIPT

Good morning, how are you doing today? **Wait for response.** Thank you for taking the time to talk with me, I have some questions for you regarding two coastal maps that I have created using aerial photography captured with drones, or Remotely Piloted Aircraft Systems (RPAS). In this interview I am hoping that we can explore how these maps can be used to communicate the impacts of climate change, I will be showing you the maps on laptop. If you would like to stop the interview at any time, please let me know. Now, if you are ready, we can begin.

<u>Part 1</u>

We will begin with a comparison of the drone maps with imagery taken from google maps. This first map is the [Central Port Mouton Wharf], from google maps. **Show participant google maps, pause for the participant to look at the map.**

Are you familiar with this wharf?

What are the greatest threats to a wharf such as this?

How concerned are you that it may be vulnerable to the impacts of climate change?

I am now going to show you a map of the [Central Port Mouton Wharf], that I helped create using imagery taken from a Remotely Piloted Aircraft System. **Show participant the 3D map of the Wharf, pause for the participant to look at the map.**

Does this type of imagery make you feel more connected to the wharf?

Can you think of any other threats the wharf may be facing?

Has this map changed your opinion on how vulnerable the wharf is to the impacts of climate change?

Now I am going to ask you the same questions but for a different site in the Port Mouton and Port Joli region. The site is a beach within Thomas Raddall Provincial Park, and this first map shows the beach from google maps. **Show participant google maps for the beach, pause for the participant to look at the map.**

Are you familiar with this site?

What kind of threats do you think a coastal region like this will face moving forward?

How concerned are you that it may be vulnerable to the impacts of climate change?

We will now look at a map of the beach in Thomas Raddall Provincial Park created using imagery taken from a Remotely Piloted Aircraft System. **Show participant the 3D map of the beach, pause for the participant to look at the map.**

Does this type of imagery make you feel more connected to the beach?

Can you think of any other threats this coastal region may be facing?

Has this map changed your opinion on how vulnerable the beach is to the impacts of climate change?

Part 2

Were you aware that RPAS (drones) can be used to create maps such as these?

Could you see any potential issues with the use of RPAS to create coastal maps such as the ones that we created?

Who do you think would find these maps valuable?

Are you aware of the new Nova Scotia Coastal Protection Act?

If the participant answers 'Yes'. In what ways do you think that maps such as these could support the Coastal Protection Act?

Do you think that maps such as these could aid in the conservation of species at risk in coastal areas?

Do you see any value in using drones to create more maps of coastal infrastructure and ecosystems in Nova Scotia?

What do you think would be most useful for these maps to capture?

APPENDIX IV: LINKS TO RPAS MAPS

Below are links to the 3D RPAS maps displayed on ArcGIS Online.

Central Port Mouton Breakwater:
https://dalspatial.maps.arcgis.com/apps/Styler/index.html?appid=f070ba93bcc742d39929d585cab0ff46

Thomas Raddall Provincial Park:
https://dalspatial.maps.arcgis.com/apps/Styler/index.html?appid=655b13125f3540e4b101b3678e86e622