ESTIMATING CHANGE OF AMPHIBIAN WETLAND HABITAT FOR PAINTED ROCK ISLAND, LAKE OF THE WOODS, FROM 1952-2015 USING HISTORICAL AERIAL PHOTOGRAPHY AND MODERN SATELLITE IMAGERY

by

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An Undergraduate Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Honours Bachelor of Environmental Management

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ABSTRACT

Radu, D. 2020. Estimating change of amphibian wetland habitat for Painted Rock Island, Lake of the Woods, from 1952-2015 using historical aerial photography and modern satellite imagery. 52 pp.

Key Words: wetland, habitat, change, amphibians, island, Lake of the Woods, analysis, landscape, conservation, aerial, photos, aerial, air, survey, satellite, landsat, GIS

Amphibians are suffering from global decline due to a synergy of factors – many of which are primarily the result of anthropogenic impacts including climate change, yet they are a crucial component of a functioning ecosystem. The importance of amphibians, the state of their decline, and an analysis of habitat is explored, with the primary intent for this thesis to observe changes to assorted wetland habitat for amphibians of Painted Rock Island, Lake of the Woods. An aerial photo dated 1952 is compared to 2015 satellite imagery using classic rephotography techniques and beginner-level geographic information systems analysis. These comparisons will prove useful to restoration practitioners and conservation scientists that might have the goal of understanding habitat changes over time specific to Lake of the Woods.

ACKNOWLEDGEMENTS

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In addition, I would like to acknowledge Natural Resources Canada and the Earth Observation Data Management System for supplying the historical records required for this thesis. I'd also like to acknowledge the creators and contributors of QGIS3, its associated plugin community, Open Street Maps, and Bing for providing the software, maps, and imagery to make this thesis possible.

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CHAPTER 1: INTRODUCTION AND OBJECTIVE

According to Hecnar (2019), information regarding amphibians and reptiles in Northwestern Ontario is relatively limited. In addition, amphibians have been suffering a global decline primarily because of human actions (Collins and Crump 2009). While data may be limited, research must start somewhere; for this thesis, it is possible to estimate changes that have occurred to amphibian habitat over time. Here, Painted Rock Island within Lake of the Woods is explored to observe these changes using historical aerial photography compared against modern satellite imagery.

The two datasets of this thesis allow for a time span analysis of 63 years; the first dataset is an historical aerial photograph of Painted Rock Island, dated October 21, 1952 provided by Natural Resources Canada. The second dataset is Bing satellite imagery, dated June 2015 and included as a component of the QGIS3 software suite.

STUDY AREA

The study area for this thesis includes Painted Rock island, of Lake of the Woods, Ontario, Canada, shown in figure 1.

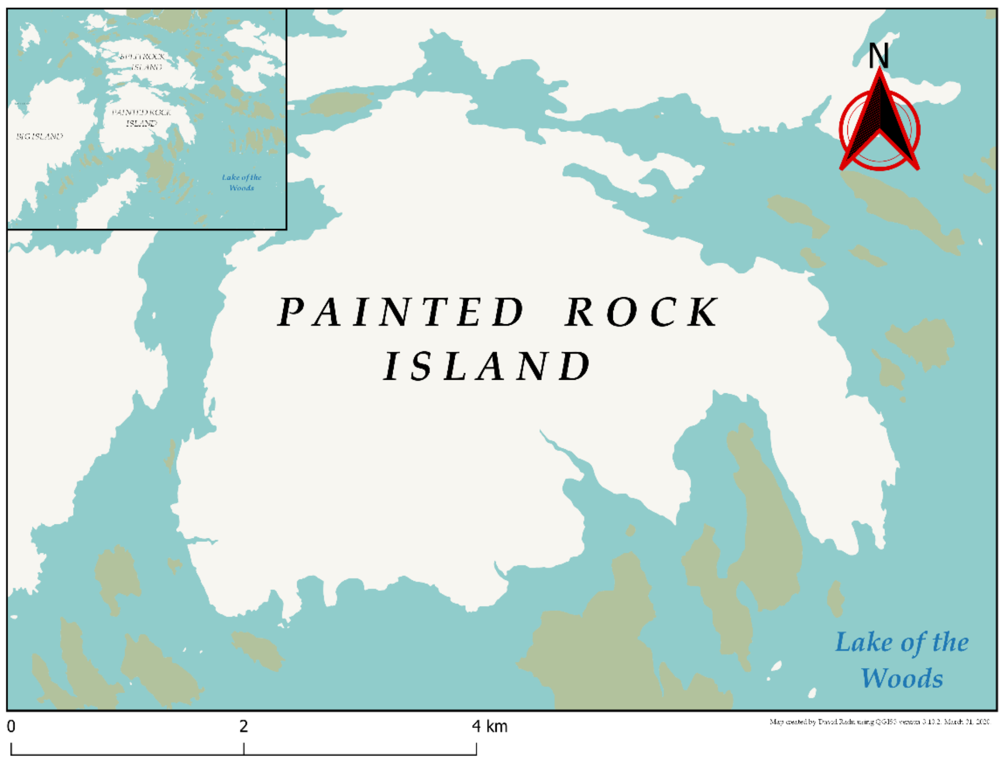

Figure 1: An overview of Painted Rock Island - the major study area within Lake of the Woods. This map was created using QGIS3 and Open Street Maps.

IMPORTANCE

Amphibians are suffering a global decline (Ontario Nature 2020). Dodd (2009) argues that amphibians are of importance based on four primary categories; economics, ecosystem function, aesthetics, and ethics.

From an economic perspective, amphibians have a wide range of uses for humans; for example, large amounts of frogs are used annually to aid with scientific training and medical research. They also have a role in the pet market and as a source of food (Dodd 2009).

Ecologically, amphibians are a very important component of a healthy ecosystem because they function doubly as predator and prey (Dodd 2009). This indicates that as a species they contribute firsthand to energy flow and the cycling of nutrients across the entire chain of connected organisms that encompass an ecosystem. For example, within an aquatic ecosystem, tadpoles consume algae - which when in overabundance can lead to eutrophication – and this is vital in maintaining excessive nutrient over-enrichment or oxygen depletion within water (Dodd 2009). Not only do these tadpoles consume algae, that energy is then available to predators that may rely upon tadpoles for sustenance. This predator-prey dynamic is emphasized for amphibians because they function as an ectothermic class of animals. Instead of relying on internal functions to regulate body heat, they instead rely on external factors (Collins and Trump 2009), which leaves more energy to be converted into growth (Dodd 2009). According to Dodd (2009), endothermic species like birds and mammals only convert 2% of their energy supply into developing new tissue, while ectothermic species like amphibians convert 25x that at 50%.

Amphibians are also important from an aesthetic perspective because of the part they play in the culture of a natural ecosystem. For example, it can be argued that the natural ambience of the outdoors at night without the sound of croaking frogs is just not the same (Dodd 2009). Across the world, frogs are also considered a good omen due to their correlation with rainfall, and amphibians in general are an inspirational driver for talent across many disciplines including art and music (Dodd 2009).

Finally, the last and arguably most important factor attributing to the importance of amphibians falls upon ethics; it can be argued that every form of life is due to be given respect, and that all living species have a right to exist (Dodd 2009).

Across the four main categories of amphibian importance – economic, ecological, aesthetic and ethical – there will be an ongoing need to preserve amphibians such that they can continue to thrive. This thesis and the observations of wetland habitat overtime are but a small piece of the puzzle yet could eventually aid in understanding why amphibians are in decline.

CONCLUSION

Lack of information regarding amphibians is clear, especially within Canada and particularly across Northwestern Ontario. It is understood on a global level that anthropogenic impacts – primarily habitat change and global warming – are causing for an overall decline in amphibian species. It is understood across the four categories of importance – economy, ecology, aesthetics and ethics – that amphibians are needed on a self-serving level for humans but also as a critical component for a functioning ecosystem. The primary component of this thesis is to observe amphibian wetland habitat changes over time, particular to Painted Rock Island. Available data allows for a time span range of 63 years (1952 – 2015) to make observations, and this could serve as valuable information for conservation practitioners in their efforts to protect amphibians moving forward.

CHAPTER 2: LITERATURE REVIEW

LAKE OF THE WOODS

Expedition logs dating back to the late 1700s show that Lake of the Woods was an important location for Indigenous peoples as a hunting and gathering site, and for European travellers as a place to seek knowledge and to facilitate trade (Henry 1809). The Europeans would trade provisions such as gunpowder and rum in exchange for supplies, primarily bushels of wild rice (Henry 1809).

Henry (1809) describes Lake of the Woods as thirty-six leagues long; for reference, a league by the late 1600s was recognized as a measure of three miles (Friedman and Figg 2000). Lake of the Woods was later described by Stephen Long as roughly 75 miles long by up to forty miles wide (Long 1824).

Long (1824) describes the scenery of Lake of the Woods as wild and romantic, noting that the shores were adorned with cliffs, hills, shrubbery and evergreens; the lake itself embellished by countless islands. The lands surrounding Lake of the Woods are described unfavourably by Long (1824), his notes indicating that the area is ‘dreary’, with disconnected ecosystems and limited natural resources or wildlife.

From the 1800s to the early 1900s, Lake of the Woods continued to be a hub to facilitate trade, and by the late 1900s permanent settlers were attracted to the area because of the copious amount of timber resources available (Anderson, et al. 2017). These settlements and advances unfortunately lead to anthropogenic effects, with characteristics of Lake of the Woods altered as early as the late 1800s by hydroelectric dam installation (Anderson, et al. 2017). With the expansion of the timber industry to Lake of the Woods, the early to mid 1900s brought upon adverse effects to the area due to land clearing for settlement and logging operations (Ruhland, et al. 2010) - especially because contaminants from industrial and residential areas were discharging into connecting rivers (Anderson, et al. 2017).

Today, Lake of the Woods is described as a complex lake spanning over 3850 km^2 and is relied upon as a primary source of drinking water for over 750,000 people (Anderson, et al. 2017). The origins of the basin's populace are derived from several sources including people from the United States, Canada, and Indigenous communities (International Joint Commission 2015). It is composed of several different types of water basins; on a general level, the south is shallow and uniform with well-mixed waters, while the north is consistent with thousands of islands, exposed Precambrian shield, and reduced productivity (Anderson, et al. 2017).

Long-term residents of Lake of the Woods have noted that the basin has been especially prone to intense algae blooms in more recent years (Ruhland, et al. 2010). Ruhland, et al. (2010) observed these changes to the Lake of the Woods basin over the last 200 years by comparing paleolimnological records to track the responses of aquatic algae over time. While algae blooms have been documented within the early 1800s, the results of their study pointed towards an understanding that indeed, the early 1900s and the installation of hydroelectric dams altered the community structure of algae within the lake (Ruhland, et al. 2010). In addition, Ruhland, et al. (2010) identify climate change as a ‘threat multiplier’, and their results indicate that changes in temperature, shorter winters and ice periods, reduced snowfall, and fluctuations of water levels are all factors that are likely contributing to these more frequent, intensified algae blooms.

Lake of Woods is politically divided across its waters with a transboundary border between Canada and the United States, supervised by the International Joint Commission – henceforth known as the IJC. According to the IJC (2015) Lake of the Woods is of significance on a cultural, social, economic and ecological level, and is subject to many anthropogenic activities including recreation, mining, forestry, and agriculture . The IJC report of 2015 indicated several concerns that have arisen over the years including but not limited to algae blooms, the presence of invasive species, and water contamination (International Joint Commission 2015).

AMPHIBIANS OF NORTHWESTERN ONTARIO

According to Hecnar (2019) there are 13 amphibians recognized within Northwestern Ontario and existing species data for this region is relatively limited. Even so, there are current and ongoing efforts to understand the distribution and range of this species guild. For instance, Ontario Nature initiated the Reptile and Amphibian Atlas, a community-based project in which individuals could take photographs and upload coordinate information for species sightings. Table 5 in appendix A includes a chart that shows an image of each amphibian and their respective sightings relevant to Lake of the Woods, while table 1 on the next page shows a condensed list of the 13 amphibians.

Table 1: The thirteen amphibians of Northwestern Ontario and their scientific name, with their respective genus and species authorities; adapted from the Society for the Study of Amphibians and Reptiles North American Species Names Database (2020).

English Name	Scientific Name	Genus Authority	Species Authority
Boreal Chorus Frog	*Pseudacris maculata*	Fitzinger (1843)	Agassiz (1850)
Spring Peeper	*Pseudacris crucifer*	Fitzinger (1843)	Wied-Neuwied (1838)
Gray Treefrog	*Hyla versicolor*	Laurenti (1768)	Leconte (1825)
American Toad	*Anaxyrus americanus*	Tschudi (1845)	Holbrook (1836)
Wood Frog	*Lithobates sylvaticus*	Fitzinger (1843)	Leconte (1825)
Northern Leopard Frog	*Lithobates pipiens*	Fitzinger (1843)	Schreber (1782)
Green Frog	*Lithobates clamitans*	Fitzinger (1843)	Latreille (1801)
Mink Frog	*Lithobates septentrionalis*	Fitzinger (1843)	Baird (1854)
Mudpuppy	*Necturus maculosus*	Rafinesque (1819)	Rafinesque (1818)
Eastern Newt	*Notophthalmus viridescens*	Rafinesque (1820)	Rafinesque (1820)
Blue-spotted Salamander	*Ambystoma laterale*	Tschudi (1838)	Hallowell (1856)
Spotted Salamander	*Ambystoma maculatum*	Tschudi (1838)	Shaw (1802)
Red-backed Salamander	*Plethodon cinereus*	Tschudi (1838)	Green (1818)

Each of these amphibians prefer a variety of habitat types. By referencing the Photo Field Guide to Reptiles and Amphibians of Ontario, habitat preferences were adapted for Hecnar's (2019) list of species as shown in table 2 on the next page (Gillingwater and MacKenzie 2015).

Table 2: This shows the common habitat selections for amphibian species seen in the region of Northwestern Ontario; adapted from Gillingwater and MacKenzie (2015) and Hecnar (2019). Note that wetlands – vernal pools, ponds, bogs, wet meadows, beaver ponds, swamps – are the most common denominator among amphibians.

Amphibian Species / **Habitat Type**	River	Vernal Pool	Pond / Marsh	Sphagnum Bog	Wet Meadow	Beaver Pond	Lake	Stream / Creek	Wooded Swamp	Old Field	Seep	Beach / Dune	Urban Areas	Coniferous Forest	Deciduous Forest
Boreal Chorus Frog		orange	orange	orange	orange	orange			pale	pale				pale	pale
Spring Peeper		red	red	red	red	red			red				red	red	red
Grey Treefrog		orange		orange		orange			orange				orange	orange	orange
American Toad		red	red	red	red	red		red	red	red		red	red	red	red
Woodfrog		orange		orange	orange				orange					orange	orange
Northern Leopard Frog	red	red	red	red	red	red	red	red	red	red	red		red		red
Green Frog	orange		orange	orange	orange	orange	orange	orange	orange		orange		orange		
Mink Frog			red		red	red	red	red	red						
Mudpuppy	orange						orange	orange							
Eastern Newt			red		red	red	red		red					red	red
Blue-spotted Salamander		orange							orange					orange	orange
Spotted Salamander		red							red					red	red
Red-backed Salamander													orange	orange	orange

AMPHIBIAN DECLINE

Amphibians are suffering; as early as 1989, humans have come to understand that amphibian populations around the world have been in decline. According to Ontario Nature (2020), 40% of amphibians worldwide are suffering from this decline. Specific to the context of Ontario, 35% of amphibians are at a recognized risk on a national and provincial level (Ontario Nature 2020). This can be largely attributed to human activity which includes many compounding parts that together globally affect amphibians (Collins and Crump 2009).

For example, land use by humans has a drastic effect on amphibians (Collins and Crump 2009). Amphibians are affected when areas of critical wildlife habitat are cleared for logging and forestry (Collins and Crump 2009). Amphibians are also impacted when entire habitats are fragmented – that means broken apart – from infrastructure development such as roads (Collins and Crump 2009). In addition, amphibians are impacted when invasive species are purposefully or accidentally introduced to different parts of the world (Collins and Crump 2009). These new species threaten the survival of native species and ecosystems because native species can be outcompeted by the new arrivals (Collins and Crump 2009). Humankind also has a history of overexploiting natural resources which has led to the demise of entire species populations (Collins and Crump 2009). Humans are also drivers of contamination, either by land, air or water and have been shown to raise toxicity levels in ecosystems to the point that adverse effects are seen upon wildlife (Collins and Crump 2009). Most notoriously of all, humans are identified as drivers of climate change – a fact accepted by at least 97% of the scientific community (NASA 2020). Unfortunately, amphibians - as an ectothermic species - are at an increased risk to climate change (Collins and Crump 2009; Corn 2005). There is also the threat of infectious diseases taking plague among species populations (Collins and Crump 2009), which has been augmented by the previous factors discussed – of those, it is suggested that critical attention must be taken to observe the impacts of contaminants on the environment and upon amphibians (Hayes, Falso and Stice 2010). Dodd (2009) reinforces these areas of concern, noting that most scientists agree that habitat modification by humans is the primary driver for the global decline of amphibians.

CRITICAL HABITAT FOR AMPHIBIANS

The term ‘critical habitat’ within Ontario is legally subject to the Species At Risk Act and is recognized as habitat that is vital to the survival and recovery for a given species labelled within the Act as either extirpated, endangered, or threatened (Government of Canada 2016). The determination of critical habitat is undergone through careful analysis of a species through a habitat identification framework that includes six steps: review of recovery strategy information such as population and distribution status, the gathering of additional information for assessment, development of appropriate criteria for critical habitat identification, application of selected habitat criteria for identification, further assessment of species and identified critical habitat, and finally a present critical habitat identification. The review and this process is observed by many different layers of judicators including the public, stakeholders, and jurisdictions (Government of Canada 2016).

On the other hand, ‘habitat’ (note: not ‘critical habitat’) is defined by the Species At Risk Act for aquatic species as “spawning grounds and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where aquatic species formerly occurred and have the potential to be reintroduced (Government of Canada 2016),” while the habitat for other wildlife species is defined as “the area or type of site where an individual or wildlife species naturally occurs or depends on directly or indirectly in order to carry out its life processes or formerly occurred and has the potential to be reintroduced (Government of Canada 2016)."

None the less, despite the global decline of amphibians, the 13 amphibians of Northwestern Ontario are not listed as extirpated, endangered, or threatened and thus are not privy to critical habitat definitions (Government of Canada 2016). Alternatively, there is an argument made from Egan and Howell (2005), in the context of the natural world, that habitat should be defined simply as an area that encompasses resources or attributes of which are ideal for a specific organism to then reside. In fact, Egan and Howell (2005) insist that habitat definitions should be specific to an organism, instead of classed by vegetation or other measures.

Despite species and environmental protection programs like the Species at Risk Act, amphibians are suffering. Foran (2019) studied the successes and failures of Canadian wildlife management practices and took the time to identify many operational flaws; the most imperative point from his research relevant to this thesis is the simple truth that as a stewardship species for this planet, humankind's reactive approach to management has been failing wildlife and natural ecosystems (Foran 2019). To be specific, humankind tends to wait until an issue is so critical – such as with the risk of a species extinction – that the damage is then likely irreversible and had they behaved more proactively to be ahead of the concerns, sustainability objectives could have been achieved (Foran 2019).

With the understanding that the legal framework by which humankind operates to direct their stewardship efforts for wildlife has been failing, compounded by the globally accepted fact that amphibians are suffering in a state of recognized decline, it can be argued that Egan and Howell's (2005) neutral definition of habitat is the most justified for species restoration, as at its core it recognizes the importance of an individual organism and observes its needs for survival through the lens of a naturally providing ecosystem.

CONCLUSION

It is understood that habitat selection for amphibian species is most commonly selected across wetlands as identified in table 2. While the Species at Risk Act does not label any of the 13 amphibian species of Northwestern Ontario as extirpated, endangered, or threatened, it is understood that amphibians are globally declining because of anthropogenic impacts – most notably habitat loss and global warming.

With the failures of critical habitat and wildlife management explored by Foran (2019), a neutral definition of habitat is suggested as proposed by Egan and Howell (2015) which places emphasis on the definition for habitat to be specific to an organism and the provisions provided by its natural ecosystem of choice. With these definitions understood, it is suggested that all types of habitat that are used by amphibians to be considered critical across all scales – both political and natural – as it is accepted that amphibians are suffering. If humans are to succeed as stewards for the natural world, it is suggested to heed Foran's (2019) advice to act more proactively instead of reactively if there is to ever have hope of restoring a species population.

CHAPTER 3: MATERIALS AND METHODS

MATERIALS

From a software perspective, analysis was performed using QGIS3 exclusively; within QGIS3, basemaps were provided by Open Street Maps and satellite imagery was provided by Bing.

An historical air photo of Painted Rock Island, Lake of the Woods was ordered and provided by Natural Resources Canada and the Earth Observation Data Management System, shown in figure 2 on the next page.

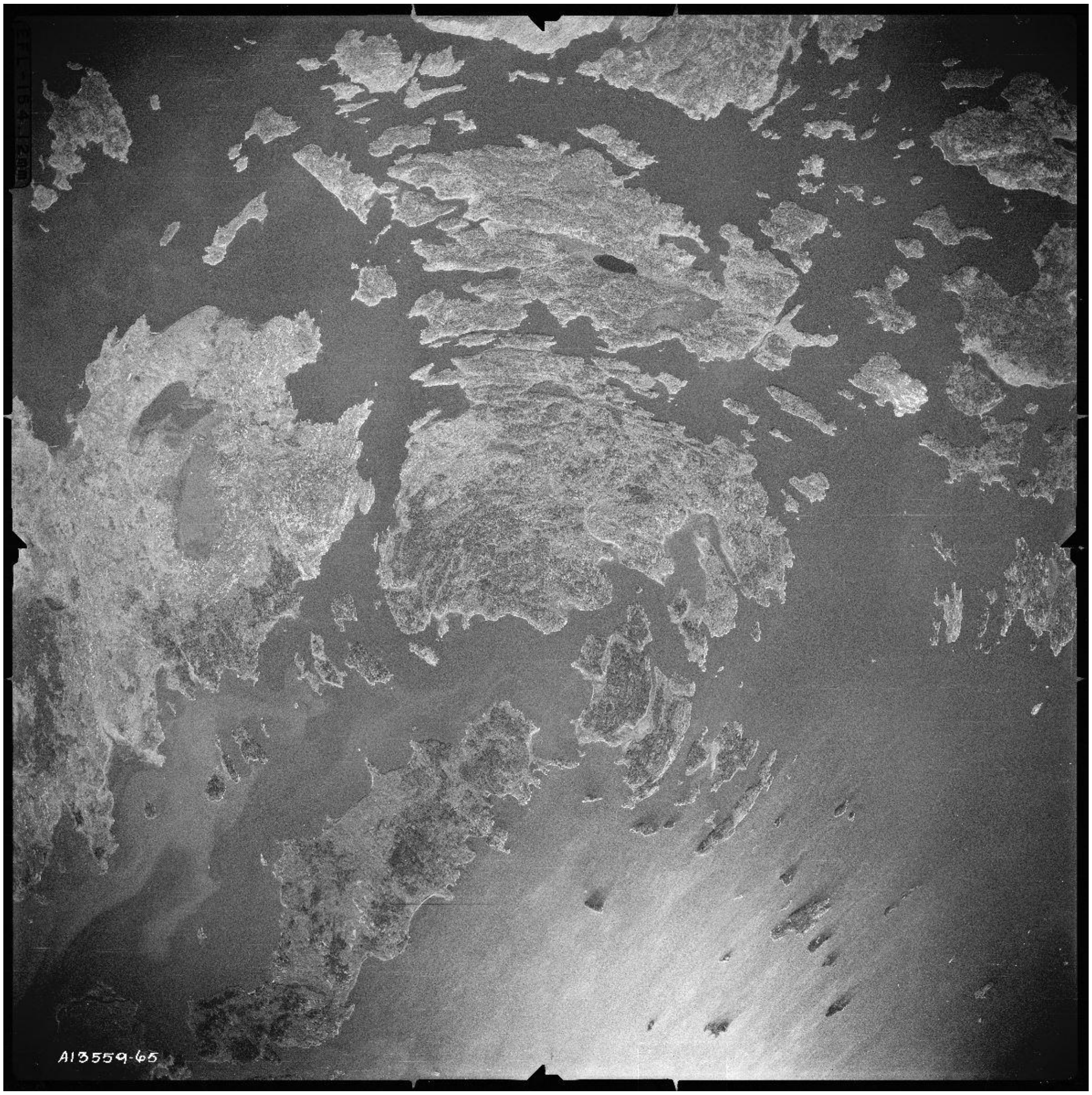

Figure 2: An aerial photograph of Painted Rock Island in Lake of the Woods, Ontario – dated October 21, 1952 (Government of Canada n.d.). This image is used as the starting benchmark to compare changes to wetland habitat over time.

METHODS

Each component of the methods was completed using QGIS3. The first step of the analysis was to georeference the historical air photo to the basemap canvas of QGIS3; this is shown in figure 3.

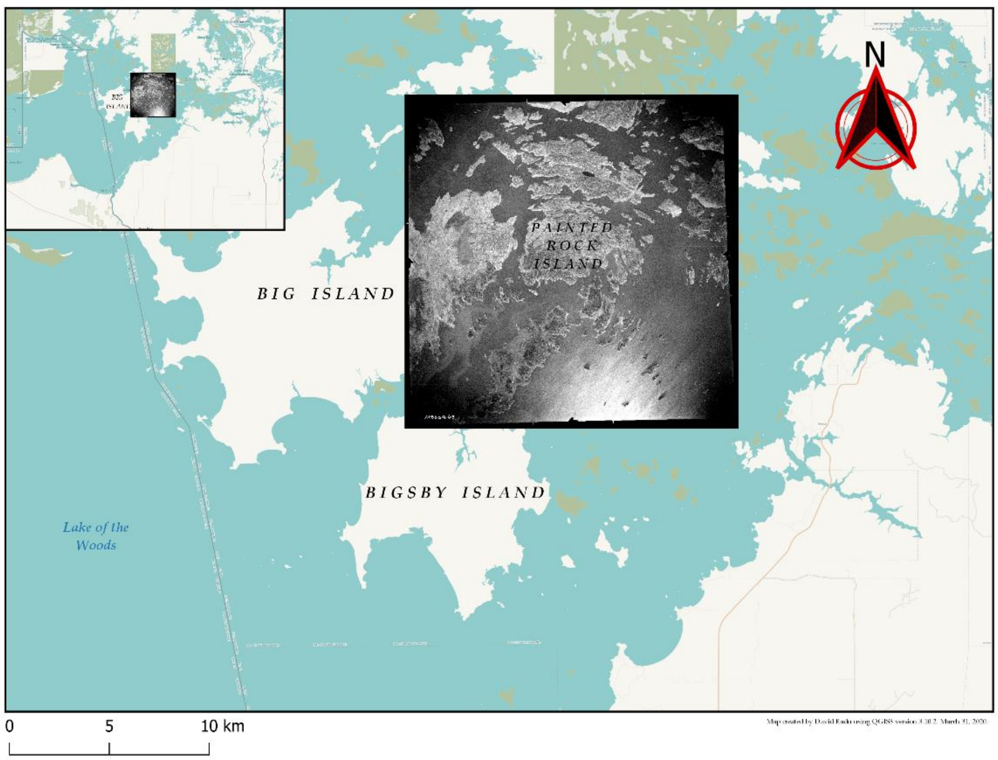

Figure 3: This is in the early stage of the assessment process; the historical air photo was georeferenced onto Bing satellite imagery which created the foundation for further analysis. This map was created using QGIS3, Open Street Maps, and Bing.

With the study area determined and air photo georeferenced, each island from each time period was then digitized onto a vector layer; figures 4 and 5 show the vectorized maps of Painted Rock Island.

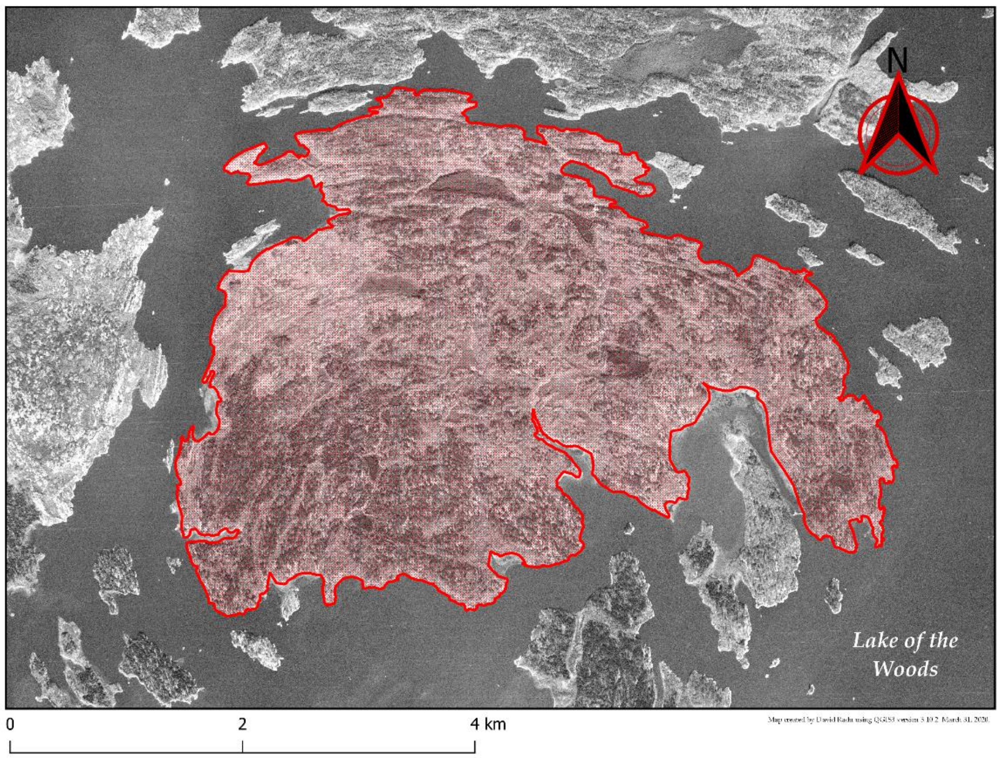

Figure 4: Painted Rock Island, October 21, 1952; the georeferenced island has been digitized and outlined. This map was created using QGIS3.

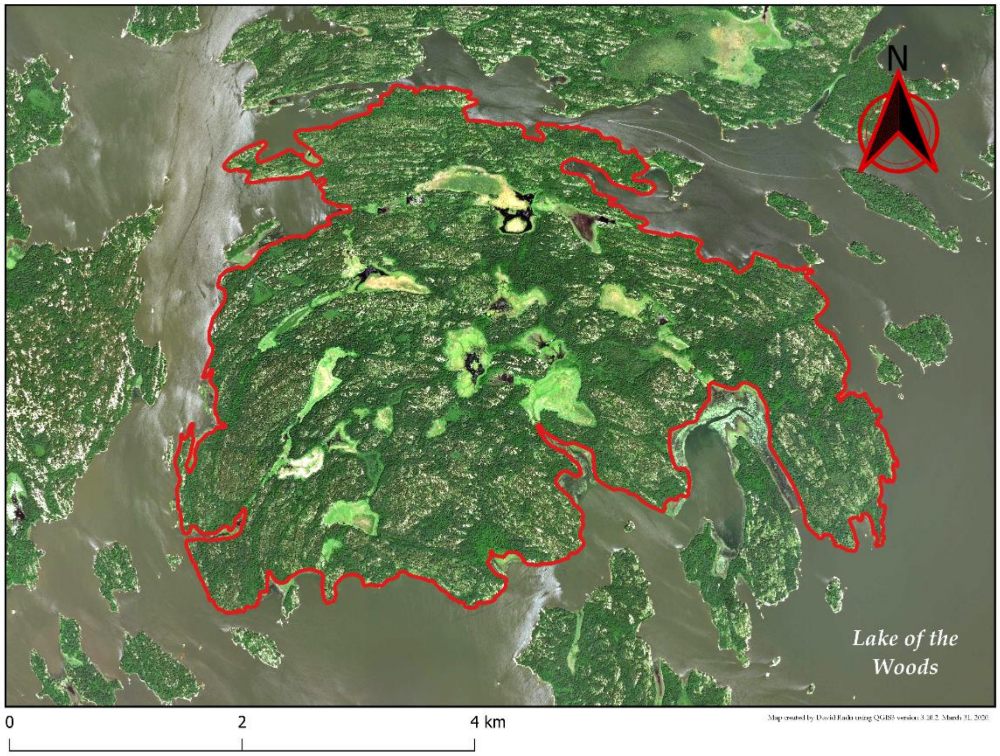

Figure 5: Painted Rock Island, 2015; the outline of the island has been digitized. This map was created using QGIS3 and Bing satellite imagery.

With the two islands digitized, an analysis on the landscape features of Painted Rock island during each time period was performed. The first step was to create a landscape feature identification matrix – shown in appendix B - that summarizes an analysis of wetland features compared between the data sets of 1952 and 2015. Appendix B also describes the identification process for land classification. Figures 6 and 7 respectively show the wetland habitat assessment for each time period.

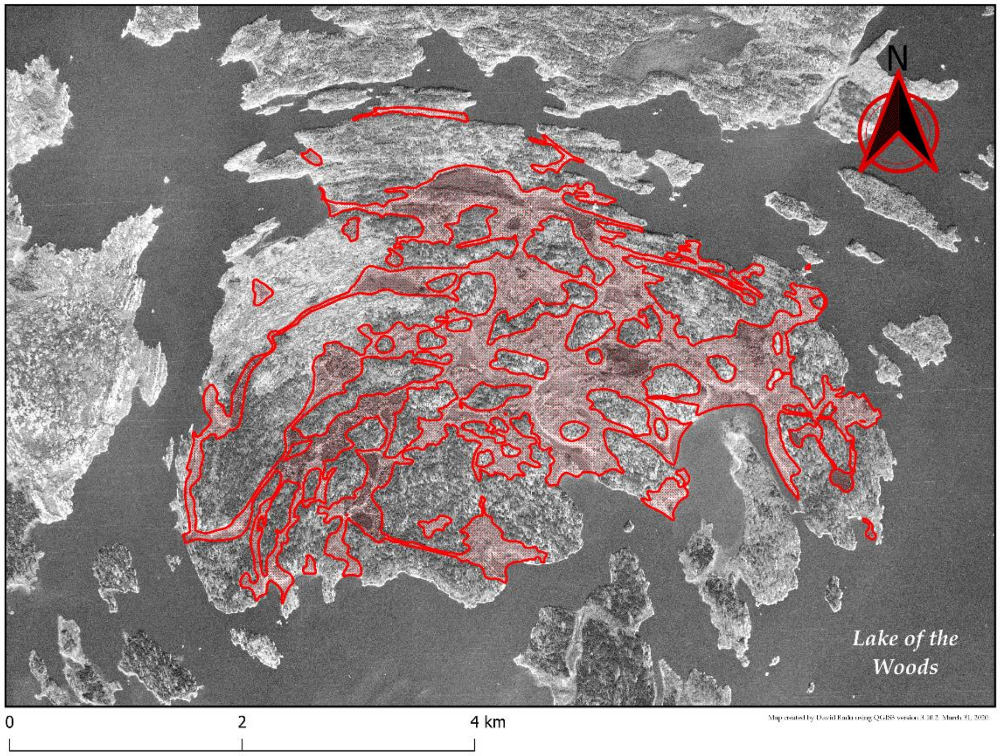

Figure 6: An analysis of wetland habitat for Painted Rock Island, 1952, following the landscape feature identification matrix in appendix B. This map was created using QGIS3.

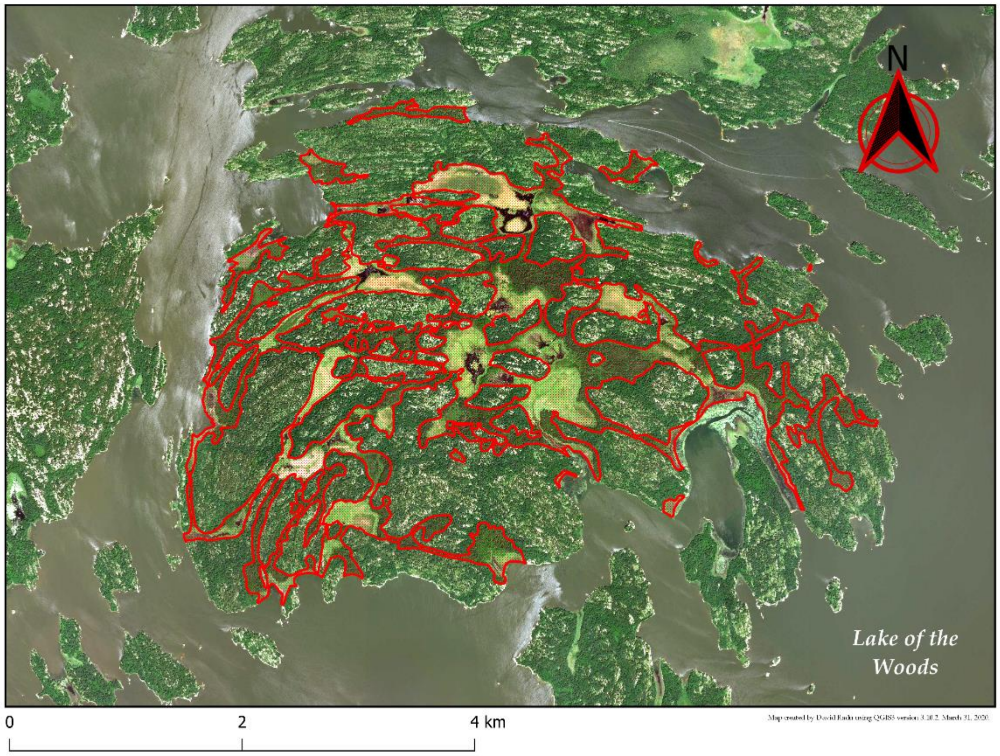

Figure 7: An analysis of wetland habitat for Painted Rock Island, 2015, following the landscape feature identification matrix in appendix B. This map was created using QGIS3 and Bing satellite imagery.

With each island and its respective wetland features identified and digitized, it was then possible through QGIS3 to perform a geometry assessment for perimeter and area using the calculate geometry plugin. In addition, each time period was assessed for totals of each wetland habitat type following the wetland features identification matrix in appendix B, and then compared. Lastly, a qualitative assessment is performed to identify landscape changes over time in greater detail.

CHAPTER 4: RESULTS

The results of the geometry assessment indicate that between 1952 and 2015 the size of the island was roughly 39 km², with an estimated perimeter of 55-56 km. According to these results, over time, Painted Rock Island has decreased in total area, reduced in total perimeter, and has lost 1.7 km² of wetland habitat as shown in table 3.

Table 3: A geometry assessment identifies island area, island perimeter and wetland area compared across each time period; data was gathered using QGIS3 and Bing satellite imagery.

	Geometry Assessment		
	Island Area (m²)	Island Perimeter (m)	Wetland Area (m²)
1952	39057671	56370	14316133
2015	39012551	55023	12600221
Difference	-45120	-1347	-1715912

A habitat type assessment was also performed across each time period to understand differences, shown in table 4 on the next page. The most significant takeaway is that over this time period, beavers predominantly took over with a total of 18 beaver dams, which converted many bog habitats into flooded areas.

Table 4: The results of a habitat type assessment performed for each time period.

Habitat Type Assessment		
Type	**1952**	**2015**
Coniferous / Dry / Bedrock	13	26
Swamp	8	9
Bog	14	4
Aquatic vegetative	10	13
Beaver dams	0	18
Flooded areas	2	16

While this thesis assesses wetlands across one broad category, analysis revealed that an abundance of habitat types were transformed over time, primarily as a result of beaver activity and flooding. Each significant area of change within the island is observed in greater detail to highlight the differences, shown in figures 8-12 on the following pages.

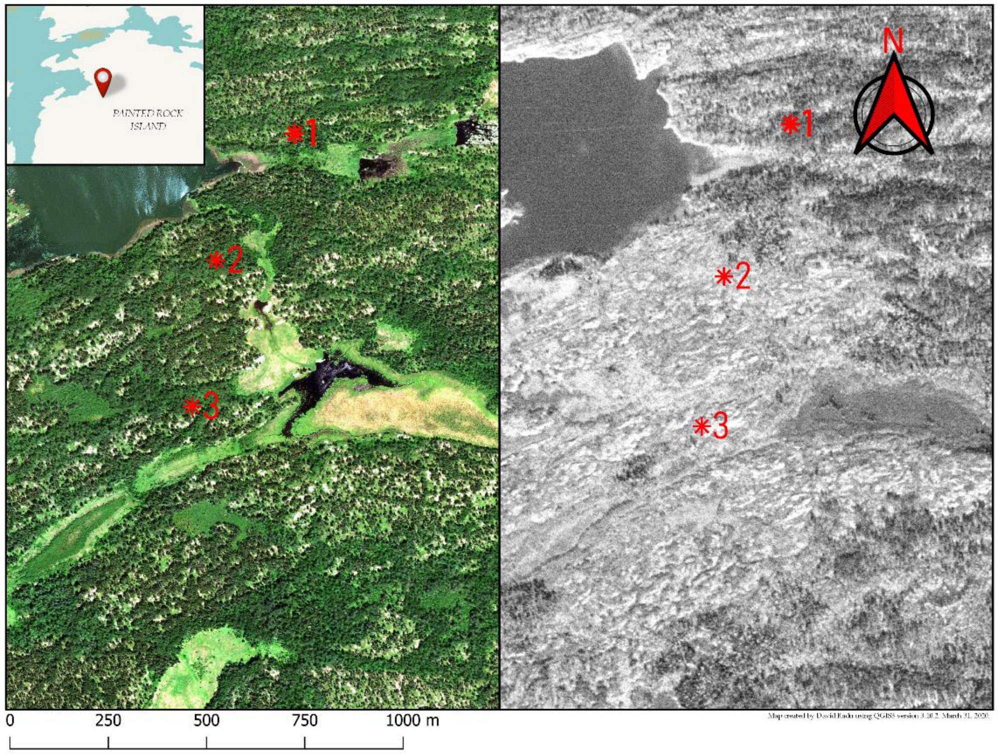

Figure 8: The northwestern sector of Painted Rock Island, 2015 (left) compared to the same region, 1952; note the three identified points. At #1 a water channel is flooded compared to 1952, evidently the result of several beaver dams having established. At #2 we see more flooding in 2015, and what appears to be exposed bedrock. At #3, we notice increased flooding again, still the result of beaver activity – of note here, however, is the clear identification of the creek in 1952 being lost to the flooding in 2015. In addition, #3 in the 1952 image shows greater definition in landscape, suggesting further the area was once exposed bedrock. This map was created using QGIS3, Open Street Maps, and Bing satellite imagery.

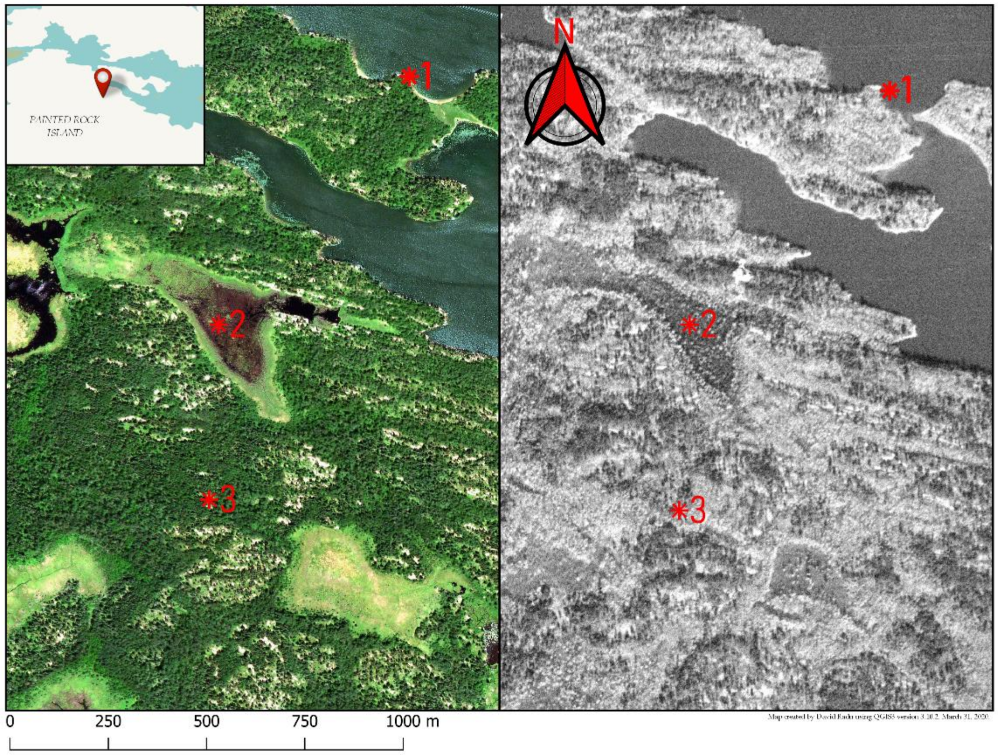

Figure 9: Left (2015), the northeastern sector of Painted Rock Island compared to the same region, 1952; note the three identified points. At point #1 we can see a distinct difference in shoreline and aquatic vegetation build-up. Marker #2 shows increased flooding in an area that looks like it was once a bog habitat in 1952. To the left and right of point #3, more wetland structure is identified in 1952 vs the flooding of 2015. This map was created using QGIS3, Open Street Maps, and Bing satellite imagery.

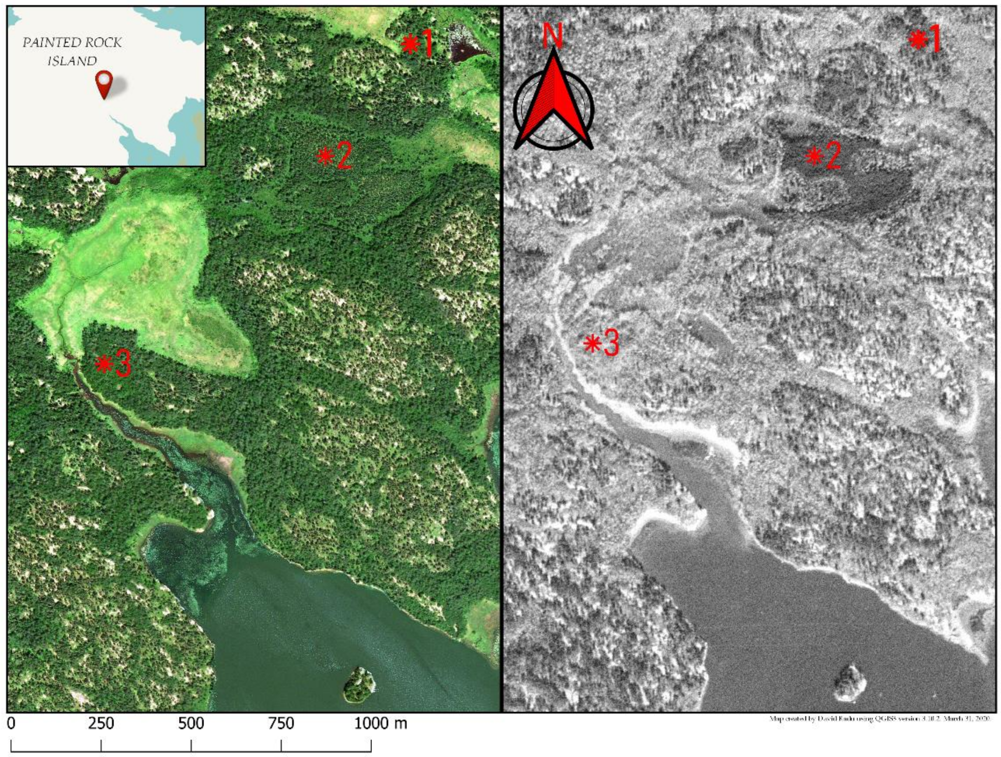

Figure 10: The southeastern sector of Painted Rock Island - 2015 (left) compared to the same region, 1952. More beaver activity is sighted at point #1, altering the wetland structure and composition along points #2 and #3. Note that in the 1952 variant at point #3 that the forest hooks upward; in 2015, the forest has receded overtime. It is difficult to distinguish changes in the shoreline, however variations in aquatic vegetation are noted. This map was created using QGIS3, Open Street Maps, and Bing satellite imagery.

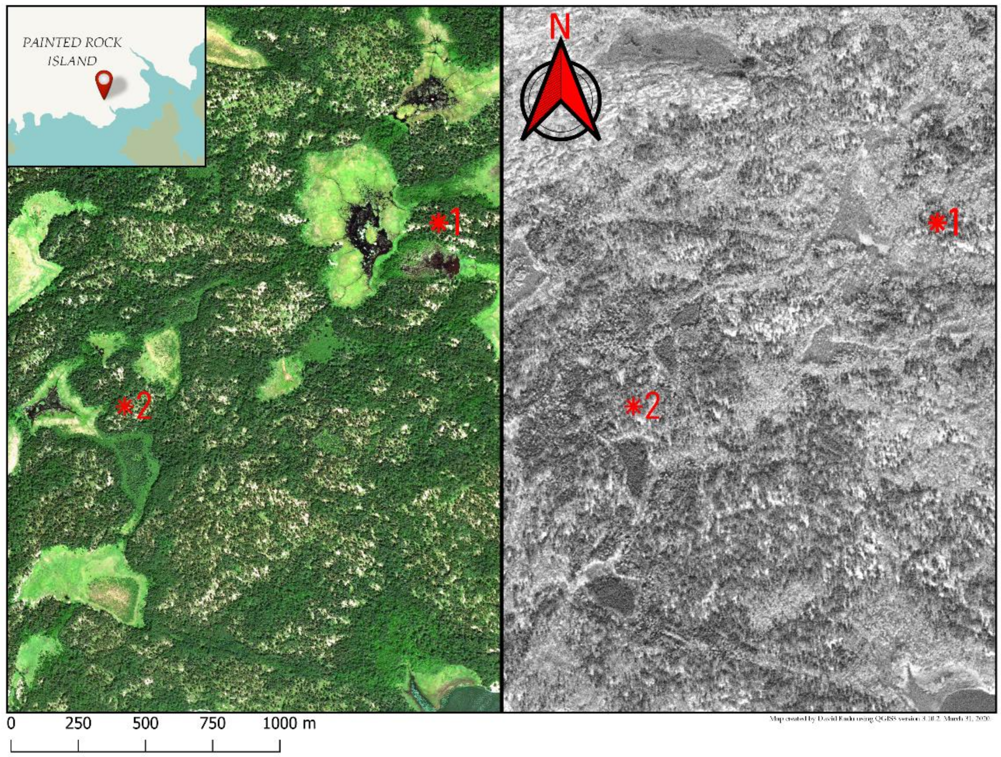

Figure 11: The southern area of Painted Rock Island laden with wetland habitat. Comparing 2015 (left) to 1952, ample beaver activity is noted by several dams and the immense amount of flooding inferred. At point #1, we see a dam to the north, west, and south, while at point #2, we see another dam to the west. It is noted here that the entire chain structure of bog habitat along point #2 has been heavily altered. This map was created using QGIS3, Open Street Maps, and Bing satellite imagery.

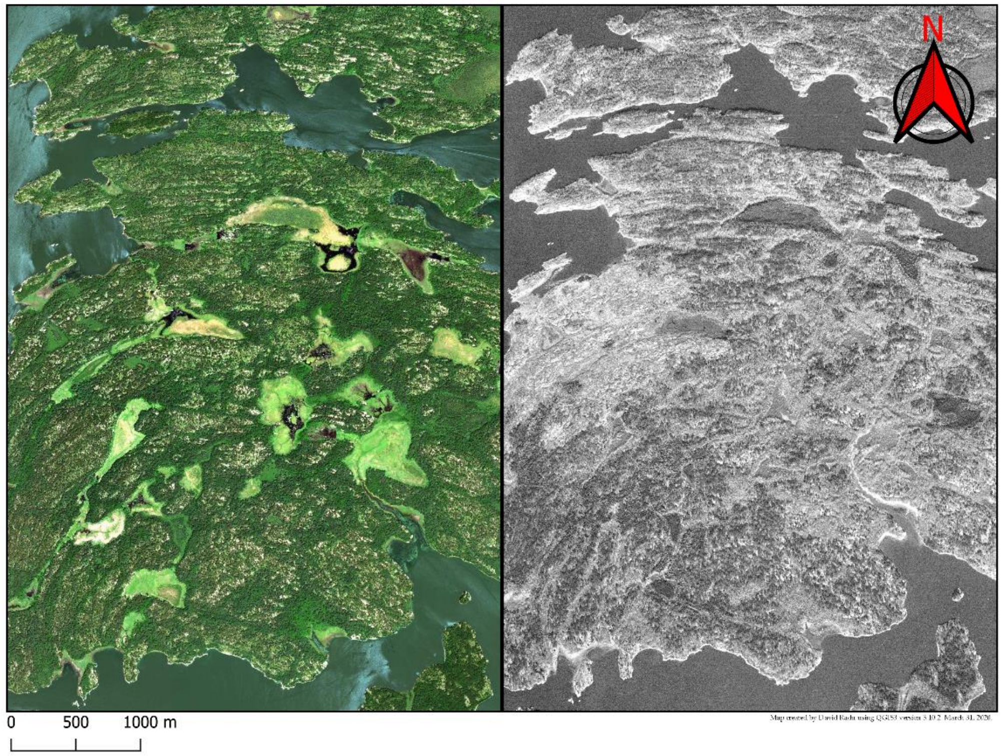

Figure 12: A large scale overview of Painted Rock Island (left, 2015) compared to 1952; in general, this image summarizes visually some of the changes that have been identified. Note the overall increase of flooding in 2015 compared to 1952, and the overall change of structure for wetland habitat throughout the island. This map was created using QGIS3, Open Street Maps, and Bing satellite imagery.

DISCUSSION

The presumption entering this study was that human activity in the Lake of the Woods region would have shown stark differences in the data sets, but this was not the case. It is hypothesised that if the data set extended further – say to the 1600s – before the expansion of the timber industry, settlement, and installation of hydro dams, that anthropogenic impacts might be noticed, especially to the lake's water table. However, it is also entirely possible that Painted Rock Island has stayed relatively intact over time and free from anthropogenic impacts, which would be reasonable given the isolated nature of Lake of the Woods.

The first impression upon looking at the two data sets is that Painted Rock Island in 2015 had an abundance of more wetlands; this is ascertained from the immense amount of flooding that has occurred over the 63-year time difference. However, this assessment has indicated that in 1952, the island was larger with slightly more wetland habitat. It is not surprising that the total wetland area has remained relatively similar. While the difference in habitat type has drastically altered, an area cannot just flood itself without having available moisture somewhere; it just so happens that on a general level between 1952 and 2015 beavers starkly transformed the wetland characteristics of Painted Rock island.

Comparisons between wetland characteristics of each island data set have also shown that Painted Rock Island has changed substantially between 1952-2015 indicated by the habitat type assessment in table 4. The general takeaway to note is that in 1952, from a wetland perspective it was primarily composed of bog and swamp habitat with no recognized beaver activity. In 2015, the island was completely different having been altered by beavers, with the introduction of 18 beaver dams, 14 additional flooded areas, and the loss of 10 bogs.

These results are not to suggest that beavers are correlated in any fashion to amphibian decline, it just so happens to be the most prominent driver for change within the island during this study period. Referencing table 2, we can see that bogs are ideal habitat for 6 amphibian species, while beaver dams are ideal for 8 amphibian species - most of which overlap. Thus, beaver activity can be presumed as a good thing here as it creates more habitat for more amphibians.

It should be noted that the quantitative results in this thesis need to be understood as estimates with an uncertain degree of precision or accuracy. This is because there was a large divide between the 1952 and 2015 data sets, with the 1952 image being presented in grey scale with a lower resolution versus that of the modern satellite image offered in a crisper resolution with full colour. What this means is that more forgiveness was needed in place of uncertainty within the 1952 wetlands assessment, and thus in general had larger wetland catch areas. In addition, as a qualitative assessment these results are subjective to the reviewer. On the next pages, figure 13 shows an overall comparison of each wetland assessment, while figures 14 and 15 help to identify differences in precision and accuracy.

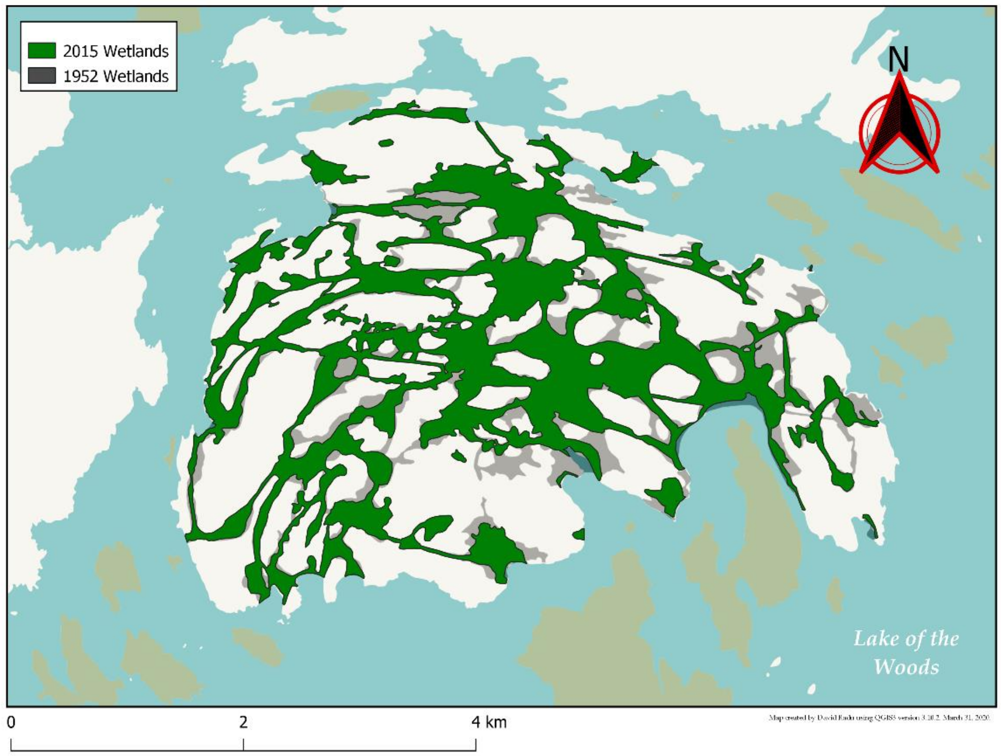

Figure 13: This map helps to identify from a large scale perspective why the analysis represents more wetlands in 1952 than 2015. Green areas represent wetlands from 2015 while the grey underlayer represents wetlands from 1952; in general, we can see that the 1952 wetlands expanded further than the 2015 wetlands. This map was created using QGIS3, Open Street Maps, and Bing satellite imagery.

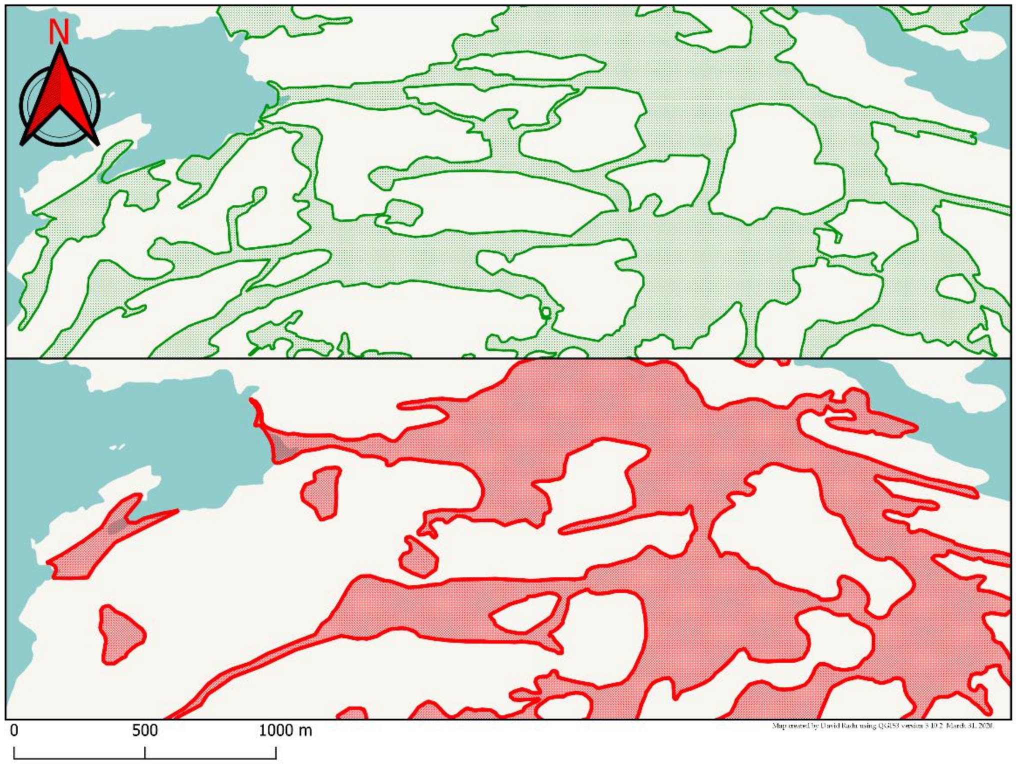

Figure 14: Upper – northern sector of Painted Rock Island wetlands assessment (2015) compared to the wetland assessment for 1952 (lower). Note that the 2015 wetlands are much more defined, while the 1952 assessment has a more broadly cast wetland terrain. This is simply because the 2015 satellite imagery had a much higher resolution and full colour, making it easier to distinguish between features and to be more precise. What this means is that by more accurately defining habitat in 2015, total area was then minimized, lowering total area counts, while the assessments in 2015 were more generalized and had increased area counts.

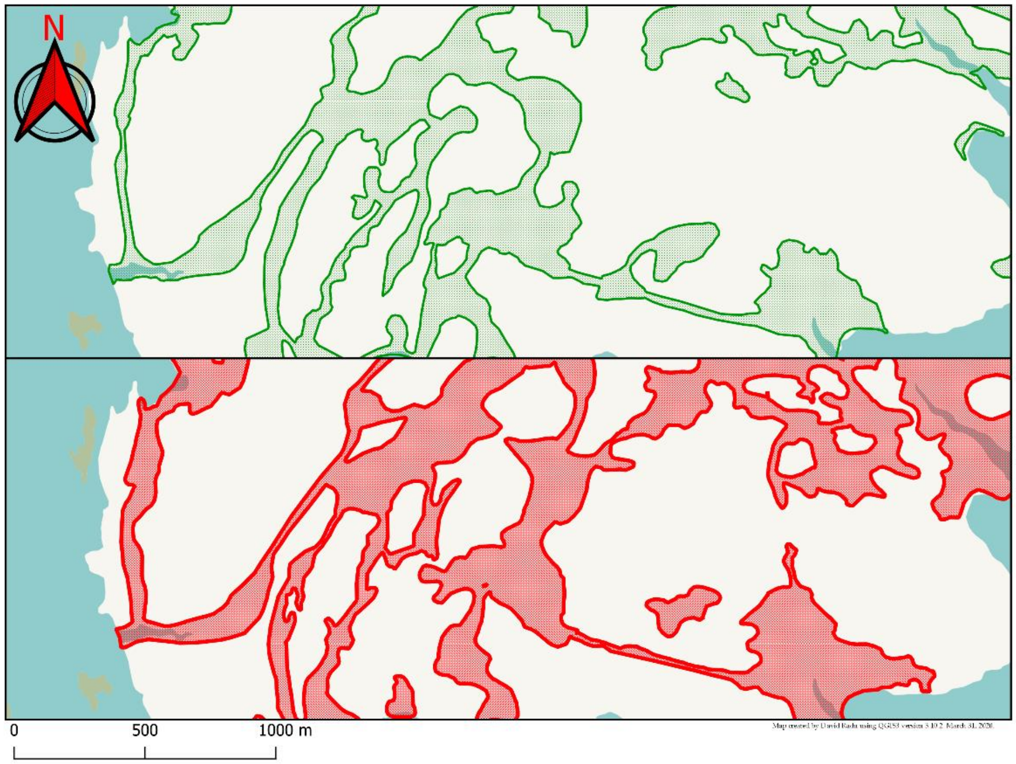

Figure 15: Upper – southern sector of Painted Rock Island wetlands assessment (2015) compared to the wetland assessment for 1952 (lower). Note again that the assessment for 2015 was much more precise and defined vs. the assessment of 1952 because of quality differences in the data sets.

While there are identified drawbacks in this qualitative assessment, the information expressed in each data set is indisputable as unaltered snapshots in time. These images are canvasses which contain a mosaic of facts; within this thesis, these facts are used to successfully explore wetland habitat changes over time.

CHAPTER 5: CONCLUSION

It is understood that information regarding amphibians is very limited, yet they are suffering a global decline from compounding anthropogenic effects, potentially made worse in North America by ongoing failures in policy for wildlife management. While this thesis does not answer the question as to why amphibians are declining, it does provide a starting point for additional research and an understanding of amphibian habitat change specific to Painted Rock Island, Lake of the Woods.

It cannot help but be wondered why there was no beaver activity on the island in 1952, when compared to 2015, most of the island had been transformed them. Was there a change in habitat characteristics specific to just Painted Rock Island? It could be that it was more of an unidentified global change to Lake of the Woods. It could also be that the situation is directly correlated to the timber industry expansion in the mid 1900s; with beaver populations being low or impacted from the influx of contaminants entering the waterbody.

The stark differences in beaver activity could also be attributed to hunting pressures, with the fur trade for beavers being highly lucrative until the 80s when the industry fell through (CBC News 2016). Interestingly, it is entirely possible that the 1952 image could be a snapshot of the anthropogenic impacts of hunting pressures while the 2015 image may be a representation of beaver recovery over time. Nonetheless, the main point to make here is that this research just points to more questions, but that is okay because these are new questions that were not previously at the forefront when trying to understand the decline of amphibians and the dynamics of wetland habitat change over time in Lake of the Woods.

This thesis is certainly limited in ways by its datasets and its qualitative methodologies, yet extremely advantaged in others. For instance, the 1952 grayscale image may be slightly blurry, some features may be difficult to discern, and some features may be skewed, but the content of the image is indisputable as a snapshot in time; if they say that a picture is worth a thousand words then I might argue that qualitatively the 1952 aerial photograph is worth a thousand facts. With that said, this thesis successfully engages, interacts with, and assesses only a small portion of the information that could be gathered from the 1952 data set.

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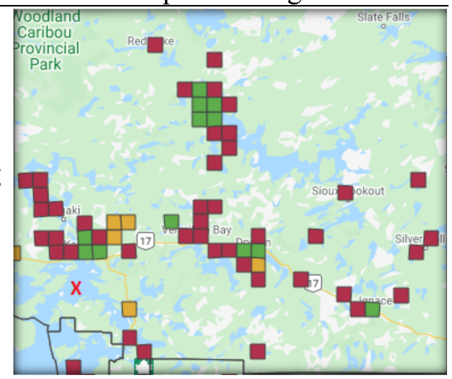
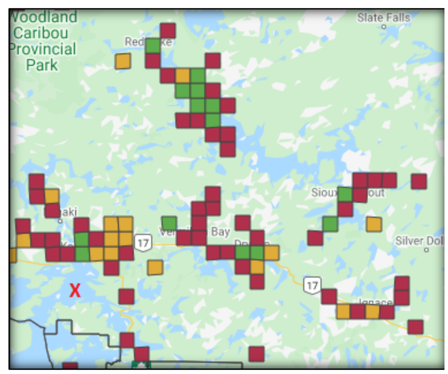
APPENDICES

APPENDIX A – AMPHIBIANS OF NORTHWESTERN ONTARIO

Table 5: Sightings of amphibians of Northwestern Ontario relevant to Lake of the Woods (marked X on each map). Red sightings are before 1999, orange sightings are after 1999, and green are both before and after 1999; adapted from the Ontario Nature Reptile & Amphibian Atlas (2020) and Google Maps (2020). Photography courtesy of Joe Crowley (2020), except for the mink frog and the blue-spotted salamander, courtesy of Scott Gillingwater (2020). The general takeaway to note is that there is little information present for islands of Lake of the Woods.

<table>
<tr><th>Photograph</th><th>Species</th><th>Spotted Range</th></tr>
<tr><td></td><td>Boreal Chorus Frog
Pseudacris maculata</td><td>
</td></tr>
<tr><td></td><td>Spring Peeper
Pseudacris crucifer</td><td>
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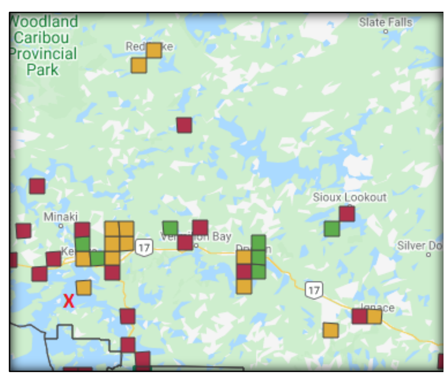
<tr><td></td><td>Gray Tree Frog
Hyla versicolor</td><td>
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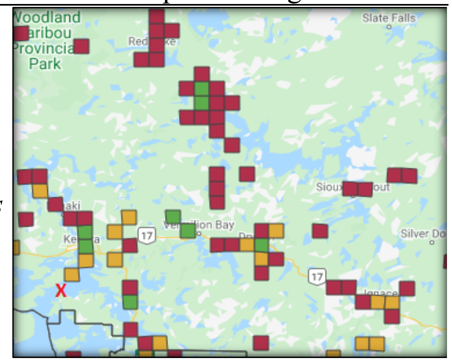
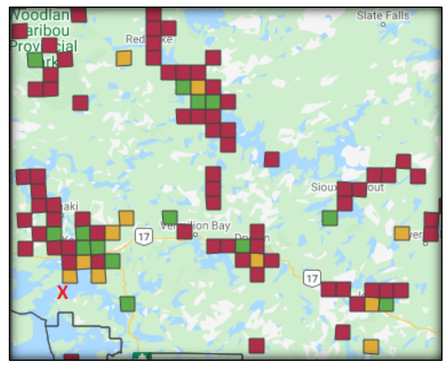
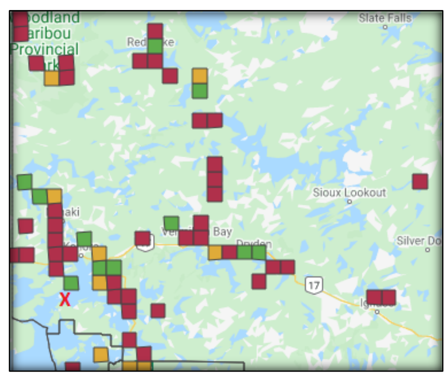
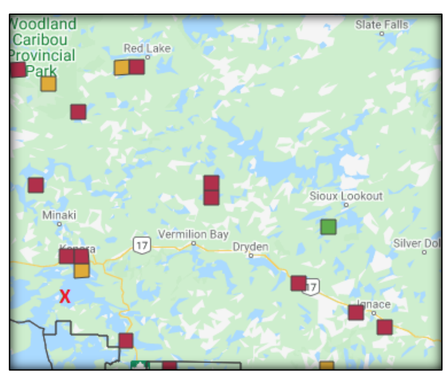
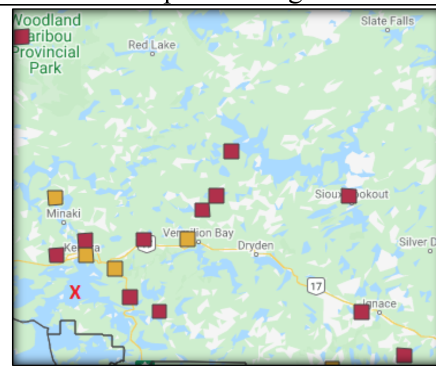
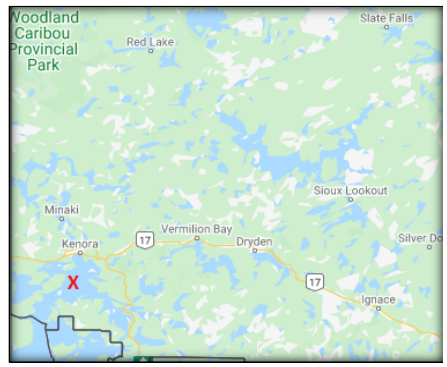
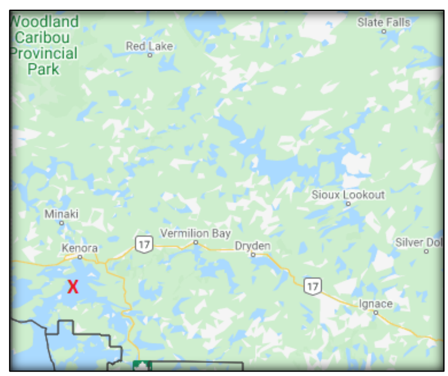
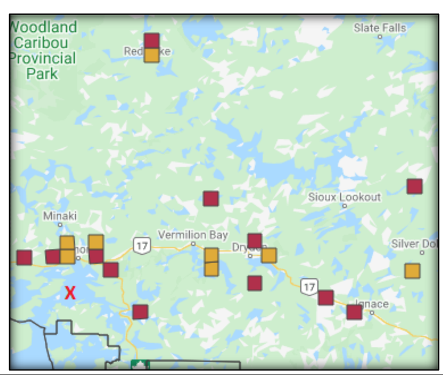
APPENDIX A – AMPHIBIANS OF NORTHWESTERN ONTARIO (CONT'D)

Table 5: Continued.

Photograph	Species	Spotted Range
	**American Toad** *Anaxyrus americanus*	
	**Wood Frog** *Lithobates sylvaticus*	
	**Northern Leopard Frog** *Lithobates pipiens*	
	**Green Frog** *Lithobates clamitans*	

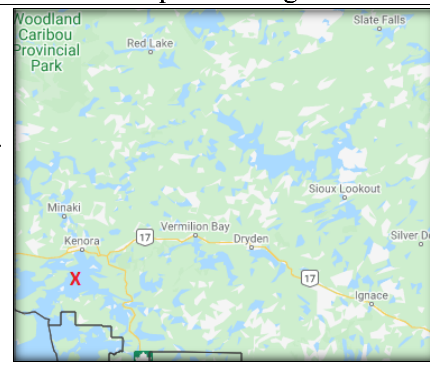
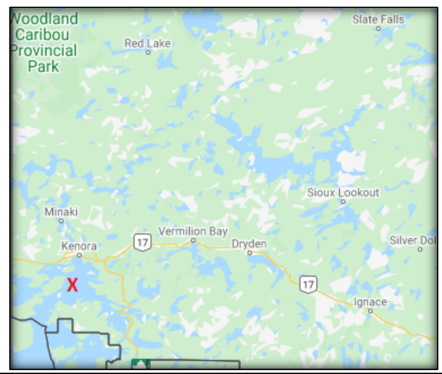
APPENDIX A – AMPHIBIANS OF NORTHWESTERN ONTARIO (CONT'D)

Table 5: Continued.

Photograph	Species	Spotted Range
	**Mink Frog** *Lithobates septentrionalis*	
	**Mudpuppy** *Necturus maculosus*	
	**Eastern Newt** *Notophthalmus viridescens*	
	**Blue-spotted Salamander** *Ambystoma laterale*	

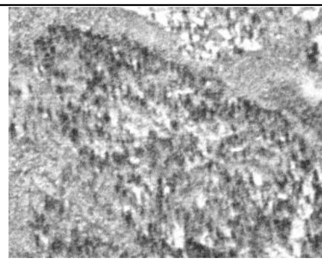
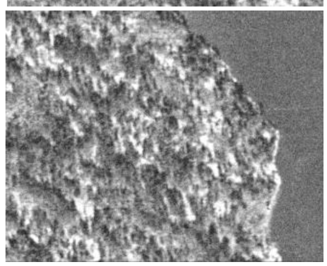
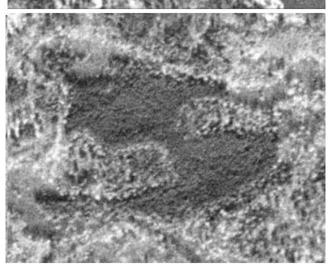
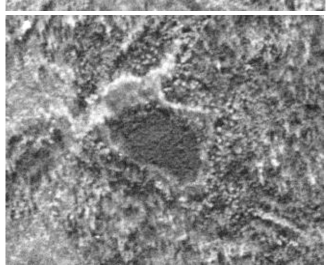
APPENDIX A – AMPHIBIANS OF NORTHWESTERN ONTARIO (CONT'D)

Table 5: Continued.

Photograph	Species	Spotted Range
	**Spotted Salamander** *Ambystoma maculatum*	
	**Red-backed Salamander** *Plethodon cinereus*	

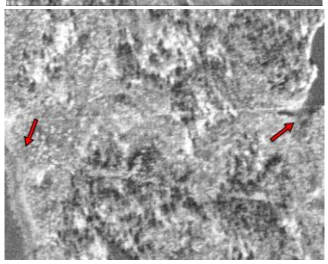
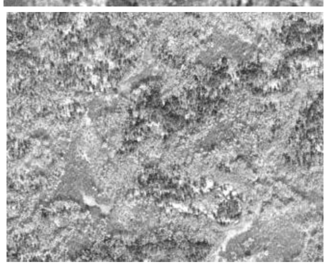
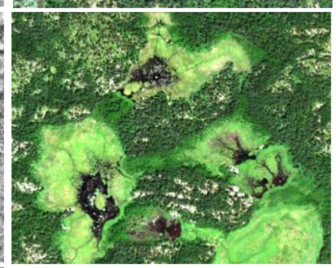
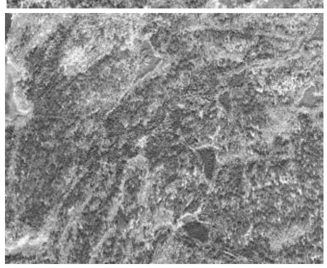
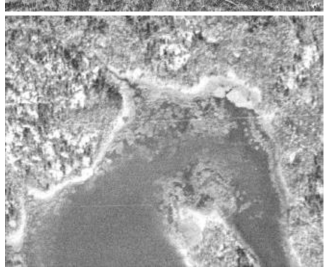
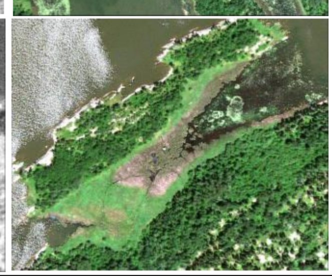
APPENDIX B – WETLAND FEATURES ID MATRIX

Table 6: This shows the key ID features for different landscapes and identifies the type of visual criterion that was used in the analysis and mapping of Painted Rock Island.

	Wetland Features ID Matrix		
Landscape Feature	**1952**	**2015**	**Description**
Coniferous Trees / Dry Land / Bedrock Example 1			Coniferous trees are identified by their upstroked conical appearance. Exposed shield rock is identified as bright white in the historical image.
Coniferous Trees / Dry Land / Bedrock Example 2			The upstroke effect of these dry, coniferous lands with exposed shield is confirmed.
Wetland Bog Example 1			Bogs are identified by their density and formation. Of note is the surrounding vegetation beside the bog that has a 'salt and pepper' effect.
Wetland Bog Example 2			There have been significant changes to this area over time, but the distinctive dense shape of the bog and 'salt and pepper' effect are confirmed.

APPENDIX B – WETLAND FEATURED ID MATRIX (CONT'D)

Table 6: Continued.

	Wetland Features ID Matrix		
Landscape Feature	**1952**	**2015**	**Description**
Swamp Example 1			Another 'salt and pepper' effect linked with wetland habitat. In the 2015 image, bright green vegation is identified as associated with wetlands.
Swamp Example 2			The 'salt and pepper' effect and bright green vegetation associated with wetland habitat is confirmed, seen here following a water channel.
Beaver Dams / Flooded Areas Example 1			Beaver dams are seen in areas with dark pools. There are no discernable beaver dams in the 1952 image.
Beaver Dams / Flooded Areas Example 2			A larger-scale context for beaver dams and flooding. Again, no discernable beaver activity is seen in the image from 1952.
Aquatic Shoreline Example 1			Shorelines with aquatic vegetation present were included in the assessment. Vegetation is distinguishable based on its patterning along the shore.
Aquatic Shoreline Example 2			Another example of aquatic shoreline / wetland habitat. Both images identify aquatic vegetation.