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Coastal Landform Change Influences on Endangered Five-Lined Skink Distribution at Northwest Beach, Point Pelee National Park, Canada

By

Evan Fortushniok

Thesis

Submitted to the Department of Geography and Environmental Studies

In partial fulfillment of the
thesis requirement for the degree of
Master of Science
in Geography

Wilfrid Laurier University

Waterloo, Ontario, Canada 2022

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Abstract

As park visitation increased to Point Pelee National Park up until its peak in 1963, the installation of infrastructure for the purpose of supporting the recreational interest grew with it. At Northwest Beach, large parking lots were built into the coastal landscape and by the 1970s large areas of sand dunes continued to be heavily impacted by the installation of visitor associated infrastructure. The infrastructure resulted in the stabilization of sand on the beach side of the parking lot, resulting in an artificially stabilized and heavily vegetated dune. Over the last few decades, the park slowly reduced the size and number of infrastructure and facilities to accommodate current visitor use trends.

This research focuses on determining the success of past management interventions that were implemented at Northwest Beach and the influence those interventions have had on restoring coastal ecosystem function and the endangered five-lined skink population. Since restoration is a long-term process, monitoring land use and land cover changes as well as outcomes of restoration activities is vital in progressing toward restoring ecosystem function and ecological integrity. The overall goal of this research is to identify the influence that coastal landform changes at Northwest Beach, Point Pelee National Park, have had on the endangered five-lined skink species abundance and distribution and to determine the success of past management interventions at Northwest Beach. Specific research objectives were to analyze change in land-use and land-cover at Northwest Beach and the influence past management interventions have had on landform change, to examine the abundance and distribution of the endangered five-lined skink population at Northwest Beach and determine the desired and most

suitable habitat for the species, and to determine the coastal landform changes influence on the five-lined skink population abundance and distribution at Northwest Beach.

This research involves the land use land cover classification of aerial imagery from five separate time periods across the Northwest Beach study area. The skink sighting abundance at Northwest Beach was comparatively analyzed with the abundance recorded throughout the entire Point Pelee National Park. The variation in abundance at Northwest Beach was evaluated along with the species distribution between the four research zones. The correlations between Northwest Beach management interventions and corresponding changes in land use and land cover as well as five-lined skink distribution and abundance were identified. Based on results of this research, additional management strategies for coastal restoration at Northwest Beach, Point Pelee were recommended. This study offers insight on the importance of specific rehabilitation practices for coastal habitat restoration to maintain ecological integrity and endangered species populations within Point Pelee National Park and broader practices that can be implemented in all coastal restoration projects.

Key Words: coastal restoration, sand dune, Five-lined skink, land-use land-cover, aerial imagery, land cover classification, endangered species

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Thank you to Point Pelee National Park for their permission to conduct research and their support in striving for the same goal of improving natural ecosystems within the park. Thank you to Parks Canada ecologists, Tammy Dobbie, and Rachel Windsor. I am extremely grateful for the time you took in helping with data collection and the knowledge you shared during field visits.

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CHAPTER 1

Introduction

1.1 Background

During the last ice age, the Laurentide ice sheet covered most of Canada and northern United States (NOAA, 2019). The massive weight and movement of the glacier carved and sculpted the underlying earth to form the lake basins. About 20,000 years ago, the climate warmed and the ice sheet retreated. The water from the melting glacier filled the basins, forming the Great Lakes. Approximately 3,000 years ago, the Great Lakes reached their present shape and size (NOAA, 2019). Point Pelee is the traditional, ancestral, unceded territory of Caldwell First Nation, the original people of Point Pelee and Pelee Island and its surrounding waters. Human connections to this land reach back at least 6,000 years as evidenced by the earliest archaeological sites (Parks Canada, 2010). First Nations peoples occupied the peninsula through the 19th century and well into the 20th until they were later expelled from the park (Parks Canada 2010). The 1830s marked the era of squatters and the first European settlement in the Point Pelee area and by 1891 there were 22 commercial fisheries operating (Parks Canada, 2010). Initially, the early settlers of Point Pelee cleared small plots and grew basic crops such as potatoes, beans, and corn. Land clearing continued with the introduction and increase of cash crop growth such as grapes, apples, and peaches (Parks Canada, 2010). In 1915, Percy Taverner and the Great Lakes Ornithological Club proposed to the newly formed Federal Commission of Conservation that Point Pelee be declared a National Park (Parks Canada, 2010).

Point Pelee National Park was established in 1918 to protect and present nationally and internationally significant natural resources and processes, particularly those representatives of the St. Lawrence Lowlands natural region (Dobbie et al., 2007). Point Pelee was Canada's first national park established specifically for conservation values (Parks Canada, 2010). Recreational use of the park by pleasure seekers began as early as the beginning of the 20th century, leading to the first cottage being built in 1910 (Parks Canada, 2010). Park visitors coming to swim, picnic, boat, and camp increased as salaries, leisure time and the number of automobiles grew. In 1922, park officials constructed roadways, improved parking lots, built bathhouses, pavilions and picnic grounds to accommodate the growing number of visitors (Parks Canada, 2010). The creation of Point Pelee National Park was based on conservation and its importance to migratory bird species, but it became subjected to heavy recreational demands as cottage developments in the park continued until the 1960s. In 1963, visitation at Point Pelee National Park peaked at 781,000, making the park the smallest yet most heavily used park of all Canadian national parks at the time (Dobbie et al., 2006). By the 1960s, Parks Canada initiated a land acquisition and rehabilitation program that included the removal of buildings, roads and additional infrastructure throughout the park (Dobbie et al., 2006). To shift the park's focus toward finding a balance with visitor use and preservation, in 1972 the Point Pelee National Park Master Plan was approved (Parks Canada, 2010). The first management plan put the park on a successful path toward supporting a much more natural environment and year-round opportunities for recreation and learning experiences for park visitors (Parks Canada, 2010). The park's efforts became focused on the protection and restoration of habitats, enhancement of visitor education and sustainment of a strong connection with the local community.

Point Pelee National Park, located at 41.7745° N, 82.6591° W at the tip of the Point Pelee Peninsula extends south into the Western Basin of Lake Erie, south of Leamington Ontario (Figure 1.1). The spit landform in Point Pelee National Park extending into Lake Erie is the southernmost point of Canada's mainland and measures 15 km² in area, making it Canada's second smallest National Park to date (Parks Canada, 2010). Point Pelee, covered by Carolinian Forest, is one of Canadas most biodiverse regions and is also home to one of Southwestern Ontario's largest segments of marsh. The Carolinian ecozone of the St. Lawrence Lowlands is the most southern biogeographic zone and is restricted to the most southerly part of Ontario (Parks Canada, 2010). The zone is highly productive due to the moderate climate, flat terrain, and rich glacial soils. Despite comprising less than 1% of Canada's landmass, this zone is the most species rich in Canada (Parks Canada, 2010). Given its southern location, in comparison to the rest of mainland Canada, the National Park is home to species not found elsewhere in the country. This includes flora species such as the hackberry, hop, and black walnut trees, as well as fauna species such as Eastern Foxsnake (*Pantherophis gloydi*) and five-lined skink (*Plestiodon fasciatus*) (Parks Canada, 2020).

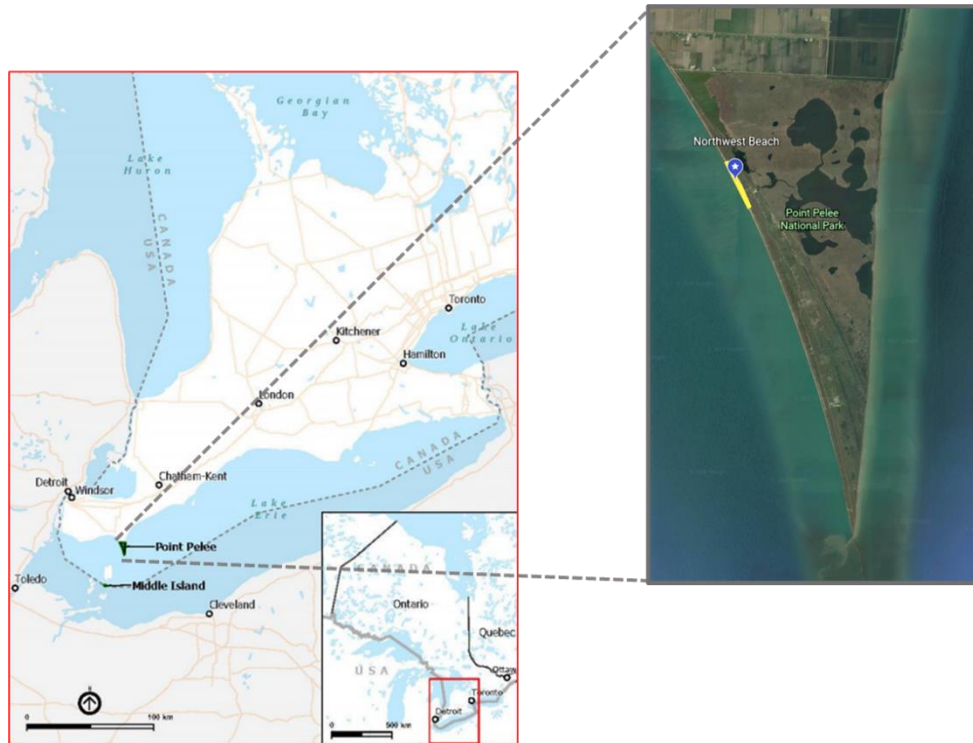


Figure 1.1: Point Pelee National Park Regional Setting. Point Pelee National Park is located at the southernmost point of mainland Canada, (Parks Canada, 2020), and Northwest Beach is visible and noted in the Google Earth image on the right (2020).

Lake Erie Sandspit Savannah (LESSS) consists of sand dunes, dune shrub lands, savannahs, and shrub barrens, generally found along the shoreline of Lake Erie's major sandspit (Parks Canada, 2020). Sandspit savannah in Point Pelee National Park is composed of three unique sections, Red Cedar Savannah (interior), Shoreline Savannah (coastal), and woodland (Parks Canada, 2020). Parks Canada (2020) noted that this specific ecosystem is extremely rare in Canada due to its southern geographic location, as there are only a few locations outside of Point Pelee National Park where it is found. Lake Erie Sandspit Savannah provides habitat for 25% of federally listed species at risk in Point Pelee National Park such as the five-lined skink, Eastern Foxsnake, Yellow breasted Chat, Common Hoptree, and Red Headed Woodpecker (Parks Canada, 2020). The composition of the sandspit savannah is dependent on periodic disturbances such as fire and shoreline processes, sand deposition, and wind and ice scour to prevent succession to dry forest,

although in the last 90 years, anthropogenic changes to the area in and around Point Pelee National Park have altered these disturbance regimes (Parks Canada, 2020). The loss of these disturbances causes the LESSS habitat to be overgrown with thickets and non-native vegetation, crowding out native plants and reducing the habitat and food sources needed for species at risk (Parks Canada, 2020).

The location of Point Pelee National Park in Essex County of Southern Ontario places the National Park in one of the most highly populated and developed areas of Canada (Parks Canada, 2013). Over 97% of this area has been altered for agriculture, industry, and urban development, emphasizing the importance of the park's ecological significance and fragility (Parks Canada, 2013). The ecological isolation and the loss of natural processes within the park threatens the viability of Point Pelee National Park's flora and fauna, making restoration efforts to create healthy habitats of high importance (Parks Canada, 2013). Over the last few decades, the park has slowly been reducing the size and number of infrastructure and facilities to accommodate current visitor use trends (Parks Canada, 2013). Parks Canada (2013) noted that since 2000 this process has included the removal of facilities and areas at Northwest Beach.

Northwest Beach (Figure 1.2) is in the center of the dune ecosystem at the north end of the park and has been modified significantly to serve as a day use area (Parks Canada, 2013). Parks Canada (2013) noted that the most heavily impacted areas of Northwest Beach contain compacted soil and gravel from the old parking lot and heavily vegetated dunes running along its western length. Remnant footpaths previously persisted through the foredune and back dune areas of Northwest Beach where boardwalk "fingers" existed (Figure 1.2) to allow visitor access to the

beach (Parks Canada, 2013). Recent rehabilitation efforts have now relocated these footpaths to the back dune and forest area adjacent to the beach. Following the decommissioning of parking lot areas, these former parking lots were colonized by invasive, exotic, and native species, including spotted knapweed, white sweet clover, and large clumps of switchgrass (Parks Canada, 2013). Parks Canada (2013) noted that the modified dune, created when the Northwest Beach day use area was developed in the late 1960s and 1970s was heavily vegetated with riverbank grape, rough leaved dogwood, eastern cedar, common juniper and invasive species such as white mulberry, spotted knapweed, bouncing bet and smooth brome (Parks Canada, 2013). The heavy vegetation and exotic species prevent the natural movement of sand into the back-dune area (Parks Canada, 2013). These areas support the best examples of hackberry forest on sand dunes and LESSS, one of the rarest habitats in the National Park (Parks Canada, 2013). Parks Canada (2013) also stated that due to the rare and sensitive nature of this site, the south end of Northwest Beach is a high priority for restoration activities (Parks Canada, 2013).



Figure 1.2: Boardwalk Infrastructure and Artificially Stabilized Foredune. These were previously located at Northwest Beach, Point Pelee National Park, and were removed to facilitate ecosystem restoration. Image's courtesy of Dr. M-L Byrne. Decommissioning of parking lot infrastructure began in 2000 with boardwalks removed in 2007 & 2008.

The area supports several species at risk and rare species, including federally listed species under the species at risk act (SARA) as the five-lined skink (endangered), common hoptree

(threatened) and dwarf hackberry (threatened) (Parks Canada, 2013). Parks Canada (2018) stated that the Carolinian population of the five-lined skink, currently listed as endangered under the SARA, is found primarily within the coastal Lake Erie Sandspit Savannah (LESSS) habitat at Point Pelee National Park (Parks Canada, 2018). This endangered species is currently monitored mainly along the west beach of the park as an indicator of the health of the coastal ecosystem (Parks Canada, 2018). Biological indicator refers to organisms, species, or communities whose characteristics show the presence of specific environmental conditions (OECD, 2001). The preferred habitat for this species has been improved over the past few decades through continued addition of woody debris and habitat restoration (Parks Canada, 2018). Parks Canada (2018) also stated that the population of five-lined skinks at Point Pelee National Park has remained in good condition over the past 20 years of monitoring. Skinks at Point Pelee National Park were experiencing a downward trend in the early 1990s attributed largely to disturbance and removal of woody debris by humans and illegal collection (Hecnar and Hecnar, 2013), however, according to Parks Canada (2018), the population numbers improved after the park began increasing critical habitat by adding more woody debris to stabilized dune areas in 1995 (Parks Canada, 2018). Restoration of the Lake Erie Sandspit Savannah habitat, which began in 2011, has also improved critical habitat for the skink population (Parks Canada, 2013).

1.2 Statement of Research Problem

As park visitation increased to Point Pelee National Park up until its peak in 1963, the installation of infrastructure for the purpose of supporting the recreational interest grew with it. At Northwest Beach, large parking lots were built into the coastal landscape and by the 1970s large areas of sand dunes continued to be heavily impacted by the installation of visitor

associated infrastructure such as boardwalks, parking bumpers and comfort stations. The infrastructure installed to facilitate beach goers resulted in the stabilization of sand on the beach side of the parking lot, resulting in an artificially stabilized and heavily vegetated dune (Figure 1.3). Park management later realized that such large-scale modifications to the natural landscape of Point Pelee National Park created adverse impacts on the coastal ecosystem as sand dunes are an essential ecological habitat for the endangered five-lined skink. The artificially stabilized dune extended for kilometers along Northwest Beach, impacting endangered five-lined skink habitat and reducing essential nesting area for the species. Over the last few decades, the park slowly reduced the size and number of infrastructure and facilities to accommodate current visitor use trends (Parks Canada, 2013). Clearly land use and land cover changes led to the destruction of sand dune habitat, critical for five-lined skink species success. The five-lined skink was listed as an endangered species in the species at risk public registry as of February 27, 2008. Parks Canada (2013) stated that habitat restoration is a top priority to conserve and protect the local five-lined skink population and Parks Canada (2018) noted that the five-lined skink is currently monitored primarily along the west beach of the park as an indicator of the health of the coastal ecosystem. Results of monitoring programs indicate that the key stressors impacting park ecosystems are habitat loss, fragmentation and alteration, shoreline erosion and regional sources of pollution (Parks Canada, 2006).



Figure 1.3: Northwest Beach Boardwalk Infrastructure and Artificially Stabilized Foredune. The artificially stabilized foredune is heavily vegetated with deciduous thicket. Image on left is looking north with the lake to the left. Image on the right is looking south with the lake on the left. Image's courtesy of Dr. M-L Byrne

Point Pelee National Park has a mandate to protect ecological integrity. Within the mandate, ecological integrity means that native species are present at viable levels and the ecological processes are present to support them (Parks Canada 2006). Parks Canada (2013) stated that since 2000 the rehabilitation process has included the removal of facilities and infrastructure at Northwest Beach. In 2000, the boardwalk along the south section of the parking lot at Northwest Beach was removed, followed by the decommissioning of the south comfort station and the remaining finger boardwalks and fence in 2007 and 2008 (Parks Canada, 2013). Following the completion of these removals, the southern two cells of the south end of the parking lot were blocked off to vehicles and the site was left to natural succession and sand movement (Parks Canada, 2013). In addition to the land use changes and the removal of infrastructure at Northwest Beach that took place in 2000, 2007 and 2008, rehabilitation management practices have continued until present. Parks Canada (2013) made several recommendations for restoration activities at Northwest Beach regarding invasive species, sand movement corridors, species at risk, maintenance, and follow-up monitoring. This was the first-time dune restoration had occurred at Point Pelee National Park, and that the restoration plan will be adaptive in nature (Parks Canada,

2013). The original restoration efforts implemented at Northwest Beach to restore ecosystem function was a cautious response to the magnitude of restoration that was required to help return the endangered five-lined skink species to a healthy population abundance, as is appropriate using the precautionary principle. Paths that were trenched through the foredune from the beach to allow sand to be transported into the decommissioned parking lots quickly filled with vegetation, largely dominated by invasive meadow species. Nayak (2018) stated that other phases followed in 2014 and in 2015 a new paved parking lot was installed decreasing the parking footprint while supporting park visitors' access to Northwest Beach in a sacrificed area. Detailed descriptions of the past rehabilitation practices and management interventions that have taken place at Northwest Beach are summarized in Chapter 2 Section 2.10.

Parks Canada continued to rehabilitate and re-establish sand dunes in the former parking lot through planting of native species (Marram grass), bulldozing, levelling and sculpting sediment to re-establish the process of sediment movement that could lead to dune formation (Nayak, 2018). Nayak (2018) initially recommended that conservation and protection of dune species such as native grasses continue as trampling of dune species is common at Northwest Beach. Reduction in foot traffic through these areas is also crucial and Nayak (2018) recommended that a designated beach front area be established. It was recommended that deciduous thicket be trimmed and thinned to maintain sediment flow to the parking lots. Finally, Nayak (2018) recommended that appropriate sand supply i.e., very fine sand grains is needed for dune development and that a sand supply be placed with appropriate grain size to facilitate this process at Northwest Beach. These recommended rehabilitation practices were further applied in the decommissioned and removed parking infrastructure area north of the newly established comfort station and parking lot at

Northwest Beach (Zone B). The location of zone B and the additional three study zone locations analyzed in this research are shown in figure 1.4. Parks Canada staff determined that bold action was required to restore ecosystem function at Northwest Beach to support a successful five-lined skink population. The gravel that based the parking lots was dug out and removed from the Northwest Beach site. In summer and fall of 2019 native vegetation species were potted and transported out of the deciduous thicket and working rehabilitation area, while invasive species were removed from the area entirely. In fall 2019 the heavily vegetated foredune was pushed overusing machinery, which dispersed and sculpted sand throughout the former parking lot area. This rehabilitation method introduced a local supply of sand to the area, reducing any ecosystem risk associated with introducing an external sediment source. This included a sediment supply that consists of grain sizes appropriate for dune development. Native vegetation species were then planted throughout the rehabilitation area. Additionally, woody debris that facilitates skink habitat was randomly dispersed throughout the site. Parks Canada continues to monitor the Northwest Beach site implementing rehabilitation practices and invasive species removal.

Point Pelee National Park, extending south into Lake Erie, contains several beaches that run along both the east and west shorelines. This research is specifically focussed on four zones (Zone A, Zone B, Zone C, Zone D) that are located at Northwest Beach study site on the western shore (Figure 1.4). The four zones delineated for this research have experienced varying magnitudes of anthropogenic influence and rehabilitation measures throughout the history of Point Pelee, elaborated on in section 2.10. Corresponding descriptions pertaining to each of the four research zones in relation to the Northwest Beach study site are detailed in Chapter 4.



Figure 1.4: Northwest Beach, Point Pelee National Park study area including locations of four specific research zones. Four research zones across Northwest Beach represent different habitat compositions with varying land use and land cover. April 2017 imagery courtesy of (Parks Canada, 2021).

This research focuses on bridging the gap between the physical landform change and the impacts that has on the existing biological interactions occurring with the local five-lined skink population. Biological interactions being focused on the abundance and distribution of the local five-lined skink population. Coastal habitat rehabilitation at Northwest Beach has been an adaptive process that continues to develop with the progression of scientific research and learning from the implementation of past rehabilitation practices. This research focuses on determining the success of past management interventions that were implemented at Northwest Beach and the influence those interventions have had on restoring coastal ecosystem function and the endangered five-lined skink population. This study tests the success of the bolder actions that were more recently implemented such as the change in land cover from the former parking lot to natural landscape. Since restoration is a long-term process, monitoring land use and land cover changes as well as outcomes of restoration activities is vital in progressing toward restoring ecosystem function and ecological integrity. Understanding sediment supply and transport to the beaches of Point Pelee National Park will be important in developing future restoration methods for assuring that dune ecosystems can naturally develop into a state of equilibrium although it exceeds the scope of this research. Similarly, increasing our knowledge of the local longshore drift along adjacent shorelines will be important in ensuring a continuous supply of sediment to the dune ecosystem, although this as well exceeds the scope of this research. These influential factors are especially important considering how sediment scarce Lake Erie shorelines, and specifically Point Pelee, have been historically and will continue to be going forward if proper measures are not implemented. Identifying the correlating trends and influences between the physical and biological factors at Northwest Beach will play a key role in developing best practices for coastal habitat restoration at Point Pelee National Park.

1.3 Research Goal and Objectives

The overall goal of this research is to identify the influence that coastal landform changes at Northwest Beach, Point Pelee National Park, have had on the endangered five-lined skink species abundance and distribution and to determine the success of past management interventions at Northwest Beach. This research goal is designed to inform and recommend future rehabilitation practices at Northwest Beach for the purpose of improving overall ecosystem function that leads to a successful five-lined skink population at Northwest Beach. To meet this goal, specific objectives are:

1. To analyze change in land-use and land-cover at Northwest Beach and the influence past management interventions have had on landform change.
2. To examine the abundance and distribution of the endangered five-lined skink population at Northwest Beach and determine the desired and most suitable habitat for the species.
3. To determine the coastal landform changes influence on the five-lined skink population abundance and distribution at Northwest Beach.

Figure 1.5 shows a workflow diagram illustrating the direction of the research from objectives to the deliverables of the research. Details regarding the research and analysis approach for meeting these objectives are described in Chapter 3 Research Methodology.

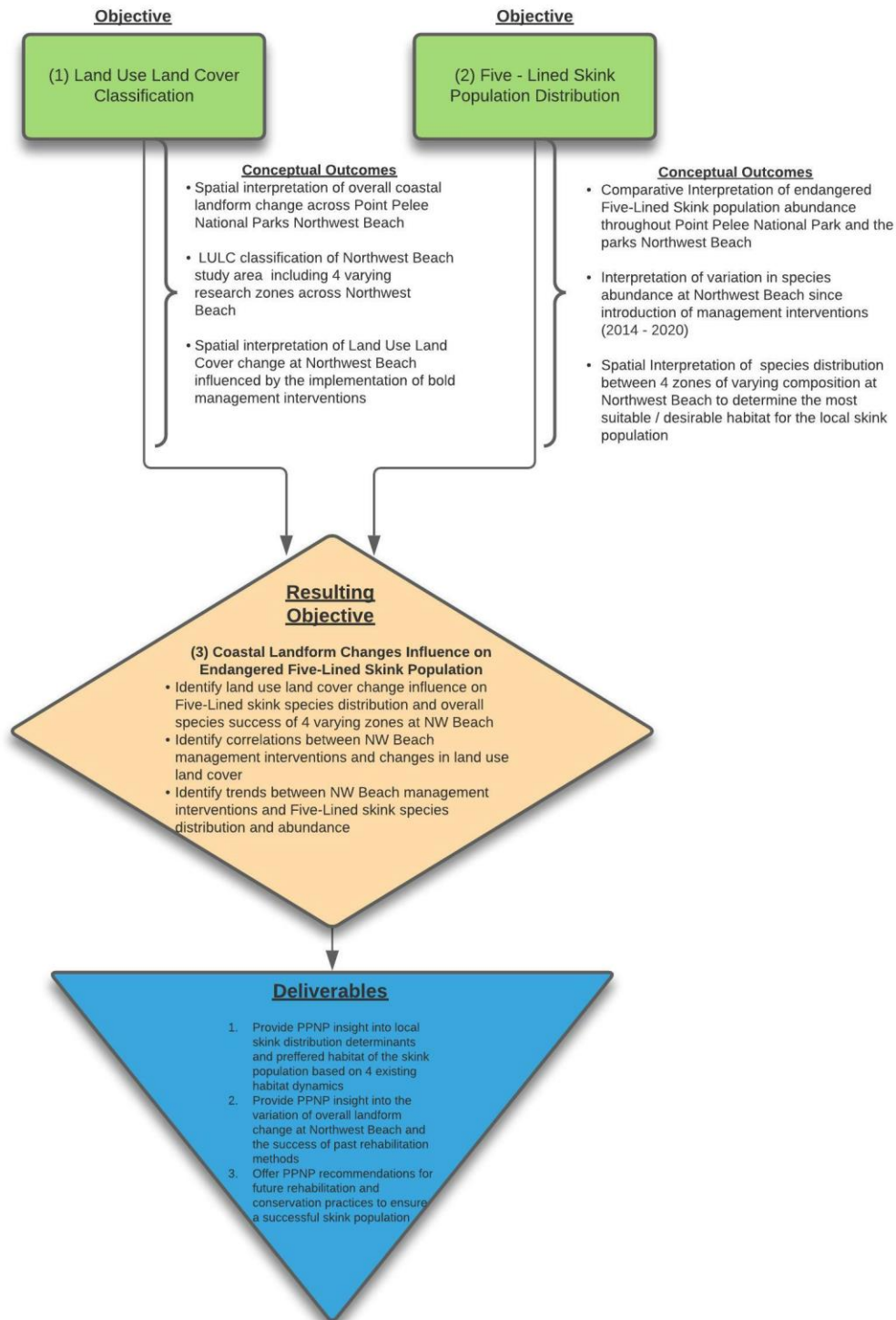


Figure 1.5: Workflow Diagram. The direction of research from objectives to the deliverables of the research is illustrated. Diagram introduces conceptual outcomes pertaining to each of the research objectives.

CHAPTER 2

Literature Review

2.1 Introduction

As the human population continues to grow at a rapid rate around the world, there is an urgent need for the preservation and restoration of coastal dune ecosystems. These unique environments are increasingly being degraded and lost as they continue to be affected by both human and ecological disturbances. The coastal environment is one of the most sought-after locations for tourism, recreation, industrial and urban development, and mining worldwide, while the associated infrastructure development places enormous pressure on coastal resources (Martinez et al., 2013). Specifically, the dune features in a beach-dune system are highly transient environments where any subtle modifications to the sediment dynamic are detrimental to equilibrium, form, and existence (Sloss et al. 2012). This could result in serious environmental and economic ramifications, further emphasizing the need for implementation of conservation and restoration measures.

Maun (2009) defined a dune complex or dune feature as the area of the coastal beach that is colonized primarily by grass, forb and shrub species extending from the beach to forested dune ridges. The development of these coastal features is dependent on the deposition, accretion and erosion of available sediment and its interaction with local vegetation. Psuty (2008) noted that coastal dunes can be found along the shores of many water bodies throughout the world, mainly in three differing landscapes consisting of sea and lake shores, river valleys, and arid regions, creating a combination of form and habitat. There are many similarities in processes and patterns

of dune form and structure within these varying systems although each landscape has its own unique features (Maun, 2009).

The formation and success of the coastal dune ecosystem is dependent on a range of characteristics such as the availability of sediment, dominant wind velocity and direction, moisture availability, types of vegetation species present, geomorphology of the nearshore and beach, local climate, wave energy and habitat modifications (Maun, 2009; Nayak 2018; Sloss et al. 2012). This research is designed to identify correlations between overall landform change in the coastal dune environment and its corresponding influence on endangered species distribution. Based on the interpretation of zones that have experienced varying degrees of anthropogenic influence, this study will determine the most suitable local habitat features and composition supporting the endangered five-lined skink population at Northwest Beach as well as identifying the most prominent landform factors impacting their population. The gap in knowledge lies in the connection between these points and the relationships between physical systems and biological interactions of the coastal dune system. Biological interactions being focused on the influence imposed on the local five-lined skink population abundance and distribution. The connection between these characteristics is the most prominent in affecting the success of the dune ecosystems at Point Pelee National Park, a beach-dune system that has been out of equilibrium since its artificial stabilization and establishment (Byrne, Dale and BaMasoud, 2013).

2.2 Point Pelee National Park

Point Pelee was established as a National Park in 1918 for the purpose of conservation as it is considered one of the most biodiverse area in Canada (Parks Canada, 2010). With nature

preserve areas quickly being established at that time in the park, cottages, stores, fisheries, and farms were developing just as rapidly (Parks Canada, 2010). Within the first decades of establishment of the park, there were plans to create a cottage community with little consideration for the natural environment (Parks Canada, 2006). With development increasing over the first few decades, many of the unique species, such as the southern flying squirrel, started to go extinct from the area (Parks Canada, 2006).

In 1963, park visitation at Point Pelee National Park peaked at 781,000, making the park the smallest yet most heavily used park of all Canadian national parks at the time (Dobbie et al., 2006). By the 1960s, Parks Canada had initiated a land acquisition and rehabilitation program which included the removal of buildings, roads, and additional infrastructure throughout the park (Dobbie et al., 2006). To shift the park's focus toward balancing visitor use and preservation, in 1972 the Point Pelee National Park Master Plan was approved (Parks Canada, 2010). The first management plan put the park on a successful path toward supporting a much more natural environment and year-round opportunities for recreation and learning experiences for park visitors (Parks Canada, 2010). The park's efforts became more focused on the protection and restoration of habitats, enhancement of visitor education and sustaining a strong connection with the local community. Today, Point Pelee attracts an average of 300,000 visitors annually, although it continues to experience overall decline in biodiversity for both flora and fauna species (Parks Canada, 2006; Nayak, 2018).

2.3 Lake Erie Sediment Budget

The development of a coastal dune ecosystem is highly dependent on sediment availability. Without a positive beach sediment budget, a negative feedback cycle will initiate beach narrowing and dune erosion by wave action (Davidson-Arnott, Law 1996). Maun (2009) noted that in most cases, the major sources of sediment for coastal dune systems consist of cliff and coastal erosion, river discharge and input from tides, and washovers with large scale changes in coastal sediment supply occurring largely because of fluctuating water levels. There are many contributing factors altering the sediment characteristics of Point Pelee, although one of the main limitations is the sediment budget. Shaw (1978) addressed the offshore and gravel dredging that had occurred in Lake Erie, just south of Point Pelee National Park that ultimately changed the sediment budget of the surrounding land mass. Beginning around 1870, sand and gravel deposits were heavily mined for the purpose of exporting materials to the United States for construction projects (Shaw 1978). Before dredging in Lake Erie came to an end in 1974, sand and gravel were extracted at an average rate of 160,000 m³ per year. In addition to dredging off the coast, Baird and Associates (2006) determined that Wheatley Harbour has trapped and removed a total of roughly 500,000 m³ of sand and gravel sediments from the shoreline. Sediment flow by littoral drift moving southward along the coast likely deposits offshore in the central basin or deep water. The removal of sand in this manner severely disrupts sediment budgets and contributes to enhanced erosion of the coast and associated features such as the beach-dune interface (Aboudha, 2003).

2.4 Longshore Drift & Sediment Transport

Masselink, Hughes and Knight (2011) note that the process of longshore drift is an essential contributor of sediment supply to the coastal shoreline. This is a process in which dominant wind

patterns and prevailing wave action transport sediment along the coast. The dominant wind directs the wave patterns that carry sediment under the influence of a current created in the surf zone (Masselink et al. 2011). Masselink et al. (2011) noted that sediment is then deposited along the coast and the process repeats, which plays an essential role in local sediment transport. Longshore drift on Lake Erie, specifically in Point Pelee, is heavily impacted by hardened erosional structures that have been installed in many areas of the shoreline (Lakhan and Trenhaile, 1989). There are several small harbours and marinas located along the shoreline, with the most impactful ones including Colchester, Kingsville, and Leamington harbours which have structures that interrupt the sediment supply to the Point Pelee National Park coastline (BaMasoud and Byrne, 2011; Dugan and Hubbard, 2006). As a result, the functioning longshore drift approaching Point Pelee from the west is not able to carry enough sediment as the harbours prevent it from ever reaching the Point Pelee shoreline (Baird & Associates, 2006). Wheatley Harbour, located east of Point Pelee, impacts the longshore current that would otherwise carry sediment to the eastern shore of Point Pelee by diverting sediment to the central basin of Lake Erie, a much deeper and larger portion of the lake than the western basin (Baird & Associates, 2006). The restricted sediment supply reaching Point Pelee is depleting the amount of available sediment on the coast, ultimately impeding the ability for dune development to occur. Wilson (1903), Terasmae (1969) in Coakley (1975) and Kindle (1933) noted that the deposition of longshore drift from eroding areas to the east and west is the major sand source needed in the formation of Point Pelee sand dunes. Without an adequate supply of sand in the beach dune system, the aeolian transport of sediment is diminished, greatly increasing the degradation on the ecosystem and loss of habitat (Nayak, 2018).

2.5 Aeolian Transport & Point Pelee Dune Formation

Once sand is on the beach, wind becomes the predominant force transporting the sediment inland and initiating dune development. Maun (2009) noted that the material that is deposited on the beach is dried by solar radiation, wind, and groundwater drainage before it can be moved toward the rear of the beach through aeolian transport. Aeolian transport is a complex process that involves four primary factors, suspension, saltation, reptation and surface creep. Suspension involves the grain sizes whose terminal fall velocity is less than the upward eddy of air currents, typically the smallest, lightest sediments. Grains are carried up into the air as suspended particles and scattered as dust (Bagnold, 1960). The suspended sediment is transported up the beach slope and distributed inland, initiating dune development (Maun, 2009). Saltation is considered the most prominent force moving sand in beach-dune environments (Maun, 2009). Wind applies a force on the grains lying on the surface, ejecting them into the air, and moving them forward until they reach the same velocity as the air. At the same time, the grains are affected by the force of gravity and begin to lose height while being propelled forward (Bagnold, 1960). The saltating grains then strike the ground at varying velocities depending on the force of the wind, starting a chain reaction when it strikes several grains on the surface, ejecting them into the wind stream as well (Bagnold, 1960). This leads to reptation or surface creep. Some of the sand grains are too large to be ejected into the wind stream. When the coarser material is hit with enough force by the saltating grains, they are propelled forward along the surface toward the dune interface (Bagnold, 1960). Aeolian transport in its entirety is the main process dictating the movement of sediment in the beach-dune system, resulting in the formation of dunes.

Point Pelee beaches have experienced and continue to be influenced by anthropogenic activity that limits aeolian transport (Nayak, 2018). In the 1960s boardwalks, parking lots and bumpers, road networks and comfort stations were installed throughout the beach-dune area of the park (Dale and Byrne, 2010). Nayak (2018) noted that human induced factors have had a negative influence on sediment transport in the beach locations. Due to the impacts of these human induced factors, sediment that could be moved through aeolian transport was getting trapped by the infrastructure in these locations, such as the fencing and boardwalks. The landscape of Northwest Beach in 1959, with the development and implementation of infrastructure, can be seen in Figure 2.1. At Northwest Beach, the infrastructure captured the sand, leading to dune associated vegetation growing up beside the infrastructure, anchoring the sand in place in an artificially stabilized foredune (Figure 2.2). This resulted in a diminished supply of sand transported to the landward area, and the natural, low dune topography could not develop. A tall foredune developed at the lakeward side of the typical dune area. The progression of this phenomenon can be seen in Figures 2.1, 2.2 and 2.3. The comparison between the 1959 and 2000 Northwest Beach imagery illustrates the influence that the associated infrastructure had on the development of this artificially stabilized foredune. The transport of sand landward occurred in breaches in the tall foredune, where paths were created for park visitors to move from the parking lots to the beach. Anthropogenic impacts such as beach raking with the use of tractors for beach cleaning have additionally affected the sediment and caused unnatural displacement of the sand grains. Raking the beach sand fluffs up the sand, making it available for landward transport. This landward transport robs the beach of sand, resulting in a wet beach, creating an environment in which invasive species are successful, outcompeting native species (Maun, 2009). Raking also degrades the local vegetation while in turn promoting the growth of invasive species (Nayak, 2018). Local

vegetation in the beach-dune interface is essential for the development of coastal dunes. Sediment moved by aeolian processes is trapped by the dune associated vegetation, gradually accumulating to form the dune (Maun, 2009).

1959 Northwest Beach Raw Imagery & Study Area Boundary

Northwest Beach, Point Pelee National Park, Ontario



Figure 2.1: 1959 Northwest Beach Point Pelee National Park raw imagery. The yellow outlined box illustrates the boundary of the research site. The imagery displays the parking lot initial development expanding southeast to northwest on the beach. The early foredune development and stabilization can be seen on the east side, adjacent to the compacted sediment of the parking lot area. (Parks Canada, 2021)

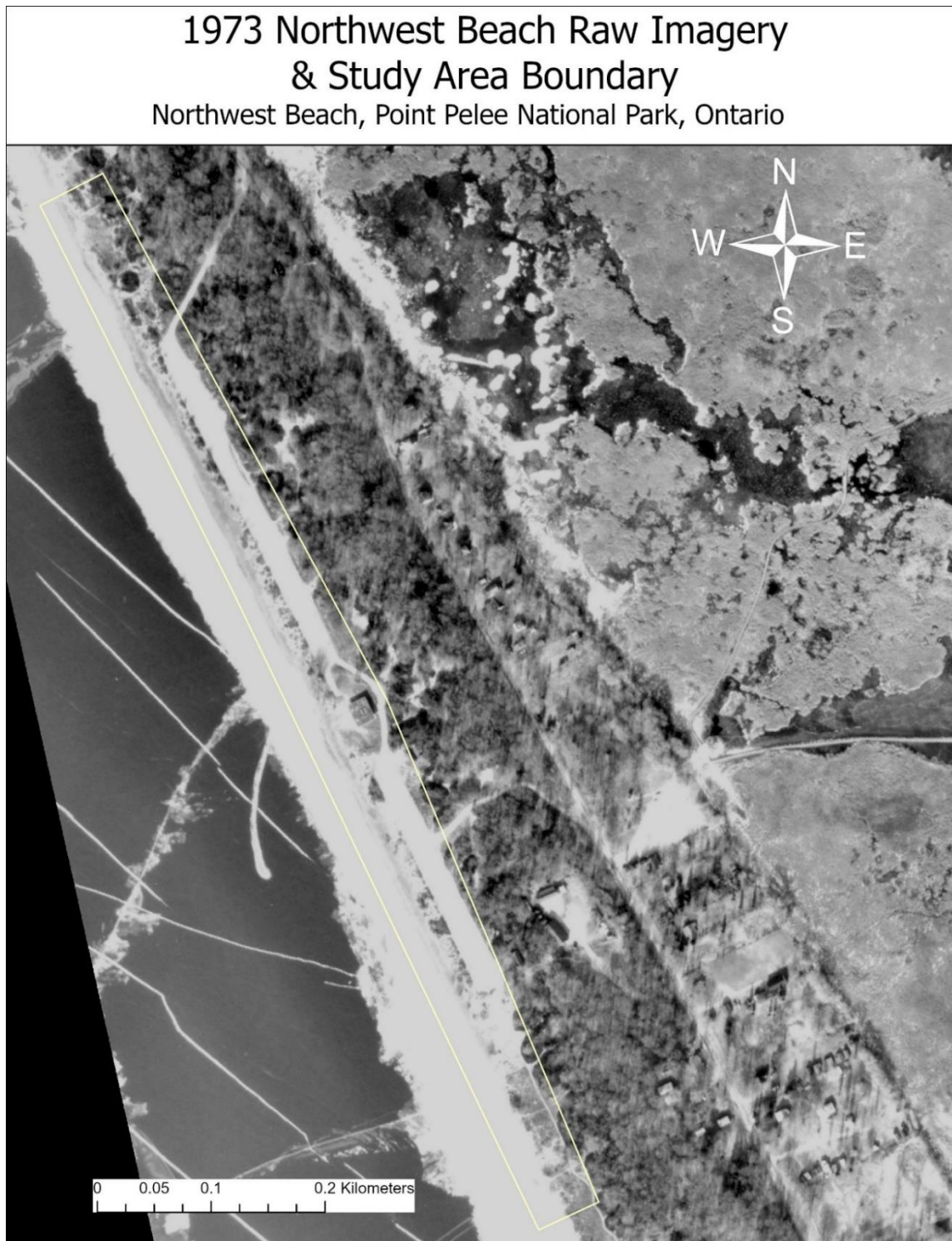


Figure 2.2: 1973 Northwest Beach Point Pelee National Park raw imagery. The yellow outlined box illustrates the boundary of the research site. Imagery displays the establishment of parking lot infrastructure and visitor facilities along with the associated foredune development adjacent to the parking lot cells. The foredune appears larger and more stabilized than in the 1959 imagery with the parking lot infrastructure and boardwalks increasing entrapment of sediment, preventing sediment transport into a backdune. Imagery was captured during winter season resulting in Lake Erie (located west in imagery) consisting of ice cover with snow being present on beach. (Parks Canada, 2021)

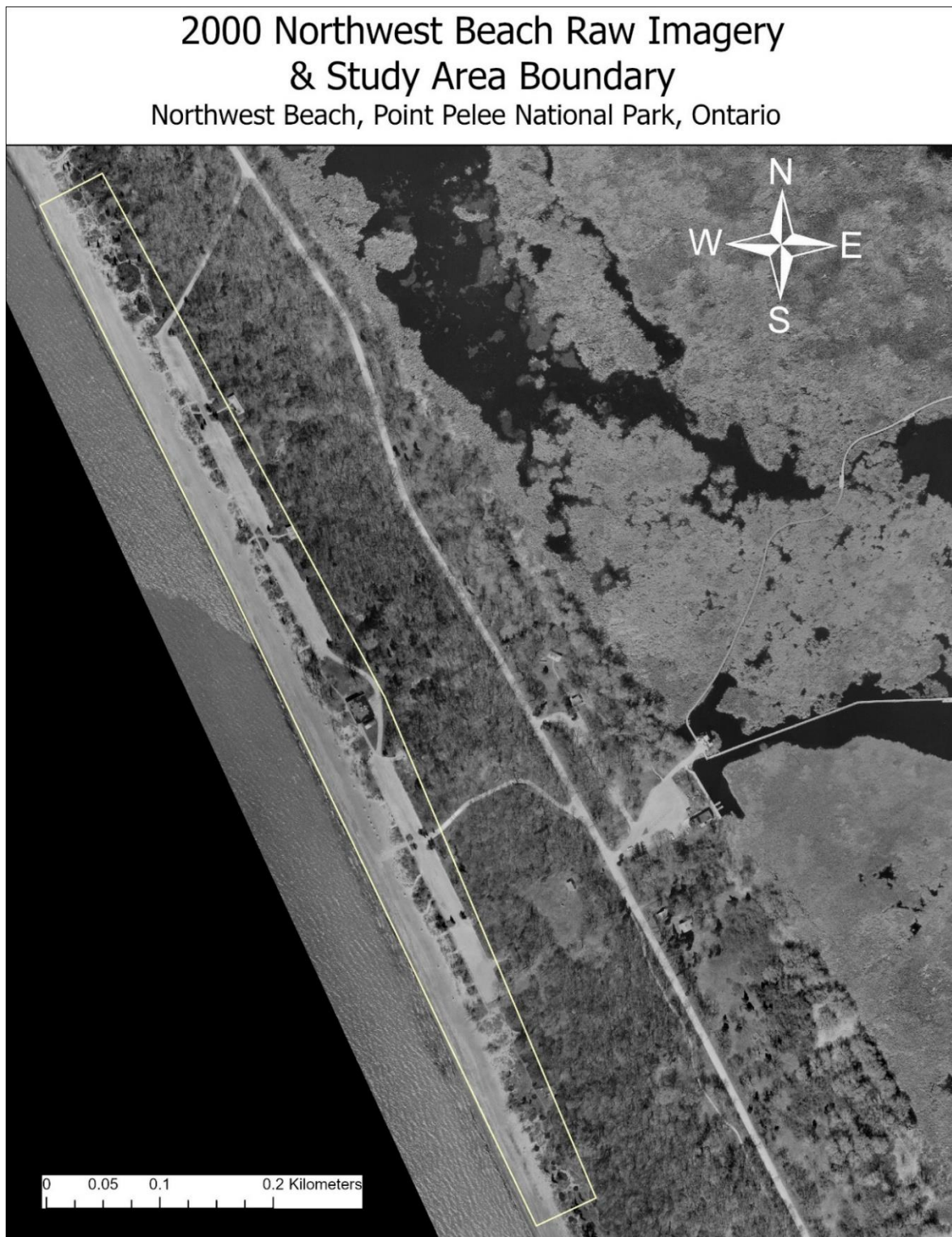


Figure 2.3: 2000 Northwest Beach Point Pelee National Park raw imagery. The yellow outlined box illustrates the boundary of the research site. Imagery displays the parking lot cells and associated infrastructure expanding southeast to northwest in the study site boundary. Foredune located adjacent (west) of the infrastructure has expanded in size and become heavily vegetated. The foredune continues to be stabilized by parking lot and boardwalk infrastructure that continues to prevent the transport of sediment towards the eastern side of Northwest Beach. (Parks Canada, 2021)

2.6 Point Pelee Dune Vegetation

The degradation and loss of local vegetation in coastal environments results in sediment deposition occurring in an unusual manner, in turn influencing the natural progression of the local dune formation process. Maun (2009) noted that for dune formation on a beach, three essential requirements must be met. A prevailing onshore wind and a continuous supply of sand, as described in section 2.5, but also an obstacle to reduce the velocity of wind to capture the sediment load being carried by the saltating cloud (Maun, 2009). Vegetation is critical in the development process of the dune, binding the sediment and reducing the rate of sediment erosion. Vegetation species reduce the wind speed, trap the moving sediment, stabilize the surface sediment, and provide essential habitat for many species (Duran and Moore, 2013). Maun and Perumal (1999) researched the effectiveness of vegetation in fortifying dunes. They determined that the fundamental dune shape is formed by the colonization of plant species and the ability to grow horizontally and vertically in response to burial by sand. Plants will increase surface roughness and absorb the energy of saltating grains, decreasing the rate of sediment transport and lowering the wind speed along the surface, leading to sand deposition on top and in lee of vegetation (Maun and Perumal, 1999). The inherent capacity of plant species and other pioneer species to grow through burial increases the overall dune height, further fortifying the dune. The most prominent dune vegetation consists of perennial species that provide cover for the dunes throughout the year, and if lost, erosion rates are certain to increase (Feagin et al. 2005).

Maun (2009) stated that in Great Lakes coastal dune environments such as Point Pelee, the most prominent and important native dune species are American Beachgrass (*Ammophila breviligulata*), European Marram Grass (*Ammophila arenaria*) and Little Bluestem (*Andropogon*

scoparius). However, Marram grass is listed as one of the most efficient species in trapping sand. The maintenance and health of these early successional species is critical as they are the most important species for dune formation. Coastal management literature emphasizes that diversity of dune associated vegetation can create necessary conditions and act as a key determinant of sand dune development (Maun 1989; Hesp 2002). The fundamental dune shape is dictated by the life form of colonizing plant species and their inherent ability to grow vertically and horizontally in response to burial by sand (Maun 2009). Historically at Point Pelee National Park, the growth of these early successional species has been suppressed by the impact on the local habitat by park visitors and anthropogenic activity, limiting the likelihood of natural dune development (Byrne, Dale and BaMasoud, 2013). The introduction and removal of infrastructure located in the beach-dune environment has additionally limited the ability of local primary successional species to be successful in this habitat (Nayak 2018). Corridors from the parking areas to the beach and informal paths created by visitors along with the associated infrastructure such as pavilions have displaced the native vegetation and limited growth along the entirety of the dune system (Nayak 2018). Beach raking with the use of tractors, a now discontinued management practice at Point Pelee, limited the successful growth of early successional species and in some cases removed the species entirely, preventing success of secondary successional species (Nayak, 2018). The impact of anthropogenic activity on beach-dune habitat reduces species diversity and evenness throughout this ecosystem, resulting in the successful growth of invasive species and their colonization within the beach and adjacent environments (Maun, 2009).

2.7 Influence of Invasive Vegetation species

Maun (1998) stated that when invasive species are introduced into an ecosystem, in most cases they multiply faster than native species, resulting in displacement. He noted that when invasive species migrate to a disturbed location and establish themselves by spreading to adjacent natural areas, it results in habitat loss for native species. MacArthur (1955) stated that species diversity contributes to the stability of the ecosystem because diversity additionally increases the frequency and complexity of interactions in a biotic community. Evenness within a community is determined by the spread of a particular species in an area and is correlated to changes in diversity (Morrison and Yarranton, 1973). Mustard et al. (2004) noted that biodiversity and its associated species evenness is extremely important for maintaining healthy, functional, and stable ecosystems. While the introduction of invasive species imposes significant environmental impacts on biodiversity and poses an even greater threat towards species at risk (Haber, 1998).

In Point Pelee National Park, invasive species are spreading at a rapid pace at the cost of native species within the decommissioned parking lots and removed infrastructure (Parks Canada, 2013). Carlson et al. (2006) determined that as of 1990, 37% of the approximate 760 plant species in the park were exotic. Nayak (2018) noted that invasive species such as spotted knapweed, white sweet clover, orchard grass, common reed, cottonwood trees and a variety of meadow vegetation have been observed in the dune-beach system at Point Pelee National Park. Parks Canada (2013b) stated that the old parking lot area is currently dominated by invasive and exotic species such as white sweet clover and spotted knapweed. The report also stated that past human disturbances have resulted in the introduction of cool season grasses into the park including smooth brome, Canada bluegrass, Kentucky bluegrass, downy chess, and creeping wild-rye (*Elymus repens*). These cool

season grasses are extremely aggressive and persistent, reducing and out-competing native warm season grasses such as little bluestem, sand dropseed and Canada wild-rye (*Elymus canadensis*), particularly in the foredune area (Parks Canada, 2013).

Both the cottonwood tree and meadow grasses have been the largest contributors to displacement and loss of marram grass within much of the beach environment in Point Pelee National Park (Nayak, 2018). Cottonwood trees typically grow in the Carolinian forested area but have begun to encroach and establish on the beach-dune environment. Johnson and Miyanishi (2007) noted that Cottonwood trees may be able to alter the environment, making it more difficult for native species to establish in these environments. Nayak (2018) noted that based on aerial imagery, Cottonwood trees were not present at Northwest Beach in 2006, while in 2015 there was an increase in their population in the beach-dune environment. The increase in meadow vegetation is another series of invasive species that introduce a level of concern for the beach-dune environment. The areas of the park that once contained parking lots, road networks and infrastructure, that were decommissioned, were simply left to allow native species to re-establish in these areas and to return the landscape to its natural composition (Byrne, Dale and BaMasoud, 2013). As previously mentioned, rather than native species beginning to colonize, meadow grass species quickly took over the area, displacing native vegetation to an even greater extent, preventing its growth in these locations in the beach- dune environment (Parks Canada, 2013). The meadow species were unintentionally introduced because of past agricultural practices within the park, signifying that it is competitive and dominant (Parks Canada, 2006). The presence of both meadow grass and Cottonwood trees suggest that they could replace the Marram grass successional species that are native to the beach-dune habitat at Point Pelee (Maun, 2009). Additionally, the

migration of these two invasive species moving toward the shoreline is indicative of an active coastal squeeze process occurring (Doody, 2013). Defra and Doody (2004) defined coastal squeeze as “a process by which coastal habitats and natural features are progressively lost or drowned, caught between coastal defenses and rising sea levels”. The changing beach-dune ecosystem challenges the ecological integrity present at Point Pelee National Park and has resulted in significant habitat loss.

2.8 Point Pelee National Park Ecology & Five-lined Skink

Point Pelee National Park is the most biodiverse park in Canada, with the beach-dune ecosystems playing a large role in the associated species abundance. Parks Canada (2010) stated that Point Pelee supports over 70 tree species, 27 reptile species, more than 20 species of amphibians, is a critical habitat for more than 380 species of migratory birds and a wide range of insects such as the monarch butterfly. The beach-dune habitat at Point Pelee supports several species at risk and rare species, including the endangered federally listed species under the *Species at Risk Act* (SARA), the five-lined skink (Parks Canada, 2013). There is only one species of lizard native to Ontario, the five Lined skink (*Plestiodon fasciatus*) which resides in the beach dune ecosystem in Point Pelee National Park (Parks Canada, 2013). Quirt et al. (2006) stated that one of the largest threats to lizard species is the loss of their habitat. Hecknar and McClosky (1998) assessed the population abundance of the native five Lined skink and determined that they have experienced declines in population, with most of the decline being attributed to conversion of suitable habitat to agriculture, urban development, and commercial and recreational purposes. The species was listed in the Species at Risk Public Registry by COSEWIC as of February 27, 2008 and was assigned an endangered status. Parks Canada (2013) noted that habitat restoration is a top

priority to conserve and protect the local five-lined skink population. Table 2.1, created by Nayak (2018), lists important features and functions of different habitats for the five-lined skink population. The resulting impacts of human activity at Northwest Beach have greatly degraded these natural features (Nayak, 2018). This research focuses on the sand dune habitat type, a habitat that is an important factor influencing their population and rated as highly disturbed. Parks Canada (2018) stated that the five-lined skink is currently monitored mainly along the west beach of the park as an indicator of the health of the coastal ecosystem. The preferred habitat for this species has been improved over the past few decades through continued addition of woody debris and habitat restoration (Parks Canada, 2018).

Table 2.1: Features, functions and disturbances status for five-lined skink habitats (Nayak, 2018)

Habitats	Features	Functions	Level of Disturbance	References and Sources
Carolinian Forest	Wood debris	Nesting	Medium	Hecknar, 1994
Sand Dunes	Basking	Nesting and hibernation	High	Vincer, 2009; Dale & Byrne, 2010
Boulders and Logs	Large rocks and logs	Provide thermal gradient & Protection from predators	Medium	Downes & Shine, 1998; Seburn, 1992

Lake Erie Shoreline	Wet and dry sand	Moisture	High	Howes and Lougheed, 2004
Beaches	Open sand	Moisture	Medium	Hecknar, 1994

2.9 Changes in Land Use Land Cover

Nowadays, monitoring land status is dominated by the use of spatial imaging technologies (Joshi et al. 2016). The wealth of remotely sensed imagery captures changes of earth's dynamic landscapes across spatial scales (Arnett et al. 2015; Chen et al. 2015). The use of aerial imagery helps gain insight into land use change processes and inform sound decisions (Mahowald et al., 2017; Newbold et al., 2015). Accompanying the rapid growth of geospatial data is a steady improvement in data analytics (Liu et al. 2018). For example, the set of algorithms for classifying land cover has been expanding, including many machine learning tools such as random forests, gaussian processes, and support vector machine (Liu et al. 2018). Despite the well-established capabilities for mapping current land status, there is a scarcity of historical land-use land cover data (Prestele et al., 2017). Modern remote sensing began long after World War II (Jensen, 2009). Maps of landscape composition prior to that are rare or nonexistent for large parts of the world, but historical landscape data have critical roles to play. They document past human impacts and provide clues on tackling current environmental issues, such as urban planning, food security, land policy, and climate mitigation (Lambin and Geist, 2008): A lack of data of the past makes it hard to build predictive understandings for the future.

Remote sensing with the use of aerial imagery has been used extensively for gaining a better understanding of land surface characteristics, dynamics and monitoring land use and land cover changes (Bartholome and Belwad, 2005; Gong et al., 2013). Land use and land cover is essential to evaluate the delayed results in the dune restoration process in the contexts of Point Pelee National Park. Land use being the main resource controlling primary productivity in ecosystem (Darwin et al. 1996) it was important to assess the patterns of land use and land cover change at Point Pelee through different time series. Sala et al (2000) stated that habitat loss is the single largest threat to biodiversity and is likely to be more significant than climate change in this century. Natural Resource Canada (2015) stated that land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil, or other. Identifying, delineating, and mapping land cover is important for global monitoring studies, resource management, and planning activities (Natural Resource Canada, 2015). Identification of land cover establishes the baseline from which monitoring activities (change detection) can be performed and provides the ground cover information for baseline thematic mapping (Natural Resource Canada, 2015). Natural Resource Canada (2015) also stated that land use refers to the purpose the land serves, for example, recreation, wildlife habitat, or agriculture. Land use application involves both baseline mapping and subsequent monitoring, since timely information is required to know when current quantity of land is in what type of use and to identify the land use changes from year to year (Natural Resource Canada, 2015). This information will help develop strategies to balance conservation, conflict uses and developmental pressures (Natural Resource Canada, 2015). Issues driving land use strategies include the removal or disturbance of productive land, urban encroachment, and depletion of forests (Natural Resource Canada, 2015).

The properties measured with remote sensing techniques relate to land cover, from which land use can be inferred, particularly with ancillary data or a prior knowledge.

The beach-dune ecosystem creates a habitat for a wide range of species all over the world, many of which include species at risk in Canada. The destruction and modification of naturally occurring habitats due to land use change is considered one of the most immediate and important threats to biodiversity (Newbold et al., 2015). To assess any results or delayed results of dune restoration, it is essential to evaluate land use and land cover. Ruiz-Luna and Berlanga-Robles (2003) determined that changes in the natural ecosystem are driven by land use and land cover change, which is driven and accelerated by natural phenomena and anthropogenic activity. Wijitkosum (2012) assessed the relationship between land use and land cover change and sediment processes of sand dunes. They determined that there is a strong impact of land use and land cover on erosion and sediment transport in the beach-dune interface, increasing the degradation on naturally occurring habitats.

Nayak (2018, p 5) stated that “conservation and protection of native species through habitat restoration remains a key challenge” and it has become increasingly clear that land use changes in Point Pelee negatively affected the protection and conservation values held by the National Parks of Canada. Parks Canada (2013) stated that since 1933, the human footprint on over 50% of dryland habitat in Point Pelee has been reduced. More than 100 hectares of agricultural fields and orchards have been removed, along with 6 commercial fisheries, 20 kilometers of roads and nearly 400 buildings (Parks Canada, 2013). Additionally, over the last few decades, as part of the National Park’s effort to “right size” the infrastructure, the park has slowly been reducing the size and

number of infrastructure and facilities to accommodate current visitor use trends. Since 2000, this process has included the removal of facilities and areas at Northwest Beach (Parks Canada, 2013). Point Pelee National park continues to progress and adapt the management process at Northwest Beach working toward restoring the ecological significance that had been impacted by past anthropogenic activity in this area.

2.10 Rehabilitation and Restoration Efforts

Point Pelee National Park has more species at risk than any other national park in Canada (Parks Canada, 2006). A key challenge for park management is in integrating the recovery and protection needs of these individual species with the maintenance and restoration needs of the Carolinian ecosystems protected within the park. Results of monitoring programs indicate the key stressors impacting park ecosystems are habitat loss, fragmentation and alteration, shoreline erosion and regional sources of pollution (Parks Canada, 2006). Formerly widespread across southwestern Ontario, the five-lined skink experienced range collapse in response to large scale deforestation that occurred across the region in the 1800s (Hecnar and Hecnar 2006). The population in the park is the largest within the region for this species of special concern. The vision for Point Pelee National Park is to protect ecological integrity. Within the vision, ecological integrity means native species are present at viable levels and the ecological processes are present to support them (Parks Canada 2006).

As stated in the previous section, over the last few decades, the park has made efforts to reduce the size and number of infrastructure and facilities to accommodate current visitor use trends (Parks Canada, 2013). Parks Canada (2013) stated that this process has included the removal

of facilities and areas at Northwest Beach since 2000. In addition to the land use changes and the removal of infrastructure at Northwest Beach that took place in 2000, 2007 and 2008, summarized in the previous section, rehabilitation management practices have continued until present. Parks Canada (2013) made several recommendations for restoration activities at Northwest Beach regarding invasive species, sand movement corridors, species at risk, maintenance, and follow-up monitoring. Parks Canada (2013) stated that as this is the first-time dune restoration has occurred at Point Pelee National Park, the restoration plan will be adaptive in nature (Parks Canada, 2013). These techniques were originally applied to the decommissioned and removed comfort station area (Zone C) and later applied to the remainder of the anthropogenically influenced areas at Northwest Beach.

Parks Canada (2013) stated that the old parking lot area is dominated by invasive and exotic species such as white sweet clover and spotted knapweed and that these species needed to be treated prior to and after restoration activities. The restoration plan indicated that mechanical removal (i.e., hand pulling) has been deemed most effective and leaves little residual impact. However, if white sweet clover flower heads have emerged, then all plants should be removed from the area. white sweet clover also responds to prescribed burning and if utilized, then a biannual plan is recommended with a fall burn being followed up by a spring burn to remove germinated plants (Parks Canada, 2013). Spotted knapweed can be removed using similar methods to white sweet clover. The cool season invasive species grasses that were introduced because of human disturbance are extremely aggressive and out-compete native grasses (Parks Canada, 2013). Parks Canada (2013) stated that only if all other possible techniques (prescribed burns, hand

pulling, or mechanical clearing) are unsuccessful, herbicides will be used as a more permanent method for site restoration.

Exotic and invasive trees were removed using mechanical removal and stumps were painted with herbicide (Parks Canada, 2013). The level of mechanical removal is relatively low and focused on the foredune and beach where poplars could be blocking sand movement. The restoration plan recommended that targeted trees, shrubs, and vines be mechanically removed by Parks Canada staff using chainsaws, brush saws, pruners and in some instances within the dune breaks, a backhoe (Parks Canada, 2013). Most of the woody debris from mechanical removal was piled in suitable areas of the old parking lot away from species at risk (SAR). These piles could be burned in late fall or early winter once no longer used for nesting or migrating wildlife. Some brush was left to provide on-going habitat for wildlife and smaller logs were strategically placed for skink habitat (Parks Canada, 2013).

Parks Canada (2013) noted that to aid in the natural sand movement and dune creation into the old parking lot area at Northwest Beach, it was necessary to create breaks in the heavily vegetated foredune. Breaks were aligned in two directions, 45 degrees facing southwest and northwest. These breaks were no more than 3 to 4 meters in width, cutting across the foredune at a 45-degree angle (Parks Canada, 2013). Breaks were constructed with a slight gradient of approximately 27-degrees upward, starting at the beach and ending in the old parking lot area. Secondly, two southwest breaks were created, also cutting across the foredune oriented at a 45-degree angle, but up to 10 meters in width to promote sediment movement from the not as strong fair-weather winds (Parks Canada, 2013). Additionally, the foredune area that had grown over was

thinned to promote further sand movement and natural dune creation (Parks Canada, 2013). Most vegetation was removed while the process was selective in leaving native species and SAR. Native species identified were potted and moved to the east side of the zone prior to rehabilitation work (Parks Canada, 2013). Parks Canada (2013) noted that logs associated with skink habitat within the selected dune break areas were moved prior to restoration activities. Areas were swept prior to the commencement of restoration activities to ensure any remaining skinks were scared away to safe cover adjacent to the work areas (Parks Canada, 2013).

Nayak (2018), stated that other phases followed in 2014 and in 2015 a new paved parking lot was installed decreasing the parking footprint while supporting park visitors' access to Northwest Beach in an area sacrificed for recreation. The study noted that following the rehabilitation measures previously mentioned, Parks Canada continued to rehabilitate and re-establish sand dunes in the former parking lot through planting of native species (Marram grass), bulldozing, levelling, and scraping sediment to re-establish the process of sediment movement that could lead to dune formation (Nayak, 2018). Nayak (2018) made further recommendations to Point Pelee National Park for the purpose of facilitating natural dune development and habitat rehabilitation at Northwest Beach. The study researched the factors that are limiting sand dune development at Northwest Beach.

Nayak (2018) initially recommended that conservation and protection of dune species such as native grasses continue as trampling of dune species is common at Northwest Beach. Reduction in foot traffic through these areas is also crucial and recommended that a designated beach front area be established. The study recommended that beach raking be stopped throughout the beach

and interpretive signs be put in place along the dune area for beach access (Nayak, 2018). The study recommended that dune species be planted to increase density to create a balance in sand accretion. This included the removal of meadow vegetation and planting dune species in the former parking lot (Nayak, 2018). Additionally, based on land use land cover (LULC) classifications, Nayak (2018) recommended that the cottonwood trees close to the shoreline that indicate a coastal squeeze should be removed. It was recommended that deciduous thicket be trimmed and thinned to maintain sediment flow to the parking lots. Finally, Nayak (2018) recommended that appropriate sand supply i.e., very fine sand grains are needed for dune development at Northwest Beach.

These recommended rehabilitation practices were further applied in the decommissioned and removed parking infrastructure area north of the newly established comfort station and parking lot at Northwest Beach (Zone B). In summer and fall of 2019 native vegetation species were potted and transported out of the working rehabilitation area and deciduous thicket while invasive species were removed from the area entirely. In fall 2019 the heavily vegetated artificially stabilized foredune was pushed over with the use of a backhoe and the subsequent sand being dispersed throughout the area that was previously parking lot infrastructure. The sand originally making up the artificially stabilized foredune was then dispersed throughout the rehabilitation area rather than importing sand from external sites that may introduce new ecosystem issues such as invasive species or inappropriate grain sizes for natural dune formation. Using the local sand supply, native vegetation species were then planted throughout the rehabilitation area with woody debris from debris piles being evenly, yet randomly dispersed for skink habitat. The area continues to be regularly monitored by Parks Canada staff with consistent rehabilitation practices being implemented including the removal of invasive species using the previously detailed mechanical

removal process. The areas north and south of the newly established comfort station and parking area continue to exclude access from the public, indicated by signs stating an active habitat rehabilitation process is being conducted.

As previously stated, this research will focus on bridging the gap between the physical landform change and the impacts that has on the existing biological interactions occurring with the local five-lined skink population. The overall impacts on habitat and the modifications that land use and land cover have on these ecosystems must be taken seriously, limiting any large-scale changes, and acknowledging how transient these systems are. Before conducting any changes to the land use, it will be increasingly important to understand the ramifications that the change will impose. It is important to understand and learn from past restoration methods that were implemented unsuccessfully and to integrate this knowledge into future restoration methodology for improving the Point Pelee coastal dune ecosystems.

CHAPTER 3

Research Methodology

3.1 Introduction

This chapter outlines the methodology used in this study. The methods for data collection and analysis of aerial imagery for LULC change classification, five-lined skink species location data and the combination of both analysis types are outlined. The overall goal of the research is to identify the influence that coastal landform change at Northwest Beach has had on the endangered five-lined skink species abundance and distribution and determine the success of past management interventions at Northwest Beach. This research goal is designed to inform and recommend future rehabilitation practices at Northwest Beach to improve overall ecosystem function that leads to a successful five-lined skink population at Northwest Beach. This chapter focuses on addressing the three research objectives designed to achieve the overall goal of the research. As described in chapter 1, section 1.3, these three research objectives are as follows:

1. To analyze change in land use and land cover at Northwest Beach and the influence past management interventions have had on landform change.

This objective involves the LULC classification of aerial imagery from five separate time periods across the Northwest Beach study area.

2. To examine the abundance and distribution of the endangered five-lined skink population at Northwest Beach and to determine the desired and most suitable habitat for the species.

The skink sighting abundance at Northwest Beach was comparatively analyzed with the abundance recorded throughout the entire Point Pelee National Park. The variation in abundance at Northwest Beach was evaluated along with the species distribution between the four research zones.

3. To determine influence that coastal landform changes have had on the five-lined skink population abundance and distribution at Northwest Beach

The correlations between Northwest Beach management interventions and corresponding changes in land use and land cover as well as five-lined skink distribution and abundance were identified.

To examine these three research objectives, five separate field visits were conducted. The first involved a reconnaissance survey to become familiar with the field context and the management practices that had previously been implemented. The following four visits were conducted for data collection involving aerial imagery collection using drone mounted sensors as well as in situ observations determining specific land cover changes that had occurred because of management interventions. Meetings and site visits were organized with Parks Canada staff from September 2019 to November 2020. Permissions for field visits to conduct data collection and data sharing agreements were obtained from Point Pelee National Park staff. For each LULC

classification, training samples for each class were collected during each of the four data collection field visits. ESRI ArcGIS Pro software was used for classification of orthophotos as well as species location data interpretation. Specific details regarding methods used to assess each objective are discussed below.

3.2 Land Use Land Cover Classification

3.2.1 LULC Aerial Imagery and Data Acquisition

Bartholome and Belwad (2005) noted that remotely sensed imagery has been used extensively to generate a greater understanding of land surface characteristics, dynamics and to monitor land use and land cover changes. The wealth of remotely sensed imagery captures changes of earth's dynamic landscapes across spatial scales (Arnett et al. 2015; Chen et al. 2015). The use of aerial imagery helps gain insight into land use change processes and inform sound decisions (Mahowald et al., 2017; Newbold et al., 2015). Observing the changes with the Land Use Land Cover Classification (LULC) will be an essential criterion for understanding the overall magnitude of landform change, the difference in landform changes between the four varying zones, the influence that the management interventions have had on landform development and how the landform change is influencing the endangered species. To perform an accurate LULC representation, the use of the same sensor, accompanied with the same spatial resolution and anniversary dates of imagery acquisition are required for proper change detection within the produced LULC classification (Lu et al., 2004). The selection of specific dates for historic imagery used within the LULC classification were based on the availability of historic aerial imagery while the most recent imagery, captured in 2019 and 2020, were collected through

four site visits using Wilfrid Laurier University Geography and Environmental Studies department eBee X fixed wing mounted drone with senseFly S.O.D.A (sensor optimized for drone applications) camera sensor. The 8-bit multispectral imagery collected for this research was subjected to the following analysis.

Four data collection periods were conducted to capture updated aerial imagery of Northwest Beach in Point Pelee National Park. Field research collection took place on May 18, 2019, December 13, 2019, September 24, 2020, and November 27, 2020. In addition to the collection of aerial imagery during these four field research trips, ground truthing was conducted for LULC verification upon the completion of the resulting LULC classification. The collection of updated aerial imagery provided the ability for this research to progress and expand on the limited existing knowledge of landform change within this area of Point Pelee National Park and provided an increased understanding of the influence Northwest Beach habitat rehabilitation practices have had on endangered indicator species inhabitants at these varying zones. The aerial imagery captured throughout 2019 and 2020 reach the full extent of the four study zones from the furthest northern border of Zone A to the southernmost border of Zone D, encompassing the full scope of the study. Details regarding the aerial imagery used within this research are below in Table 3.1.

The historical imagery used for this research to perform a classification on Northwest Beach dates to April 2017 and was provided by Point Pelee National Park, Parks Canada, originally captured and property of Ontario Ministry of Natural Resources and Forestry. This imagery and associated date of acquisition was chosen for this research based on the availability

of aerial imagery capturing Point Pelee National Parks Northwest Beach and captured after 2015 in which imagery prior to this has already had an LULC classification conducted (Nayak 2018). The dates of acquisition for the 2019 and 2020 imagery were based on scheduling availability with Point Pelee National Park for Wilfrid Laurier University eBee drone flights and local weather restriction. As a result of scheduling availability, imagery was captured during different seasons. The seasonality differences between imagery introduces error in the LULC classification process, however the influence is minor and considered a research limitation. The influence of seasonality differences on specific LULC classes is discussed in section 3.2.2. All aerial images classified for this research are 8-bit, 4 band multispectral RGB imagery using the NAD_1983_UTM_Zone_17N projection.

Table 3.1: Details of aerial orthophoto imagery used for LULC classification 2017 - 2020

Year	Type	Bands	Orthomosaic Resolution	Date of Acquisition
2017	8-bit Parks Canada Geospatial Data Aerial Imagery	4 Bands RGB	10 cm/pixel	April 2017
2019	8-bit WLU eBee X Drone Captured Aerial Imagery using (S.O.D.A.) Camera Sensor	4 Bands RGB	2.4 cm/pixel	May 18, 2019

2019	8-bit WLU eBee X Drone Captured Aerial Imagery using (S.O.D.A.) Camera Sensor	4 Bands RGB	2.4 cm/pixel	December 13, 2019
2020	8-bit WLU eBee X Drone Captured Aerial Imagery using (S.O.D.A.) Camera Sensor	4 Bands RGB	2.4 cm/pixel	September 24, 2020
2020	8-bit WLU eBee X Drone Captured Aerial Imagery using (S.O.D.A.) Camera Sensor	4 Bands RGB	2.4 cm/pixel	November 27, 2020

3.2.2 Land Use Land Cover Classification Methodology

The following methods regarding the land use land cover classification of Northwest Beach, Point Pelee National Park were designed to follow a similar procedure used by Nayak (2018), as an extension of classification work for Point Pelee National Park. The aerial imagery capturing the full extent of Northwest Beach and classified for this study consist of dates from 2017, 2019 and 2020 including five classified images in total (Table 3.1). Prior to classification,

aerial imagery was subjected to preprocessing techniques by Wilfrid Laurier University Geospatial Specialist Trina King to create accurate orthophotos for classification analysis. An orthomosaic was developed to create map quality imagery with high detail and resolution made by combining many smaller sized images referred as orthophotos. An orthophoto is an aerial photo that was corrected for lens distortion, camera tilt, perspective and topographic relief or the changes in elevation on Earth's surface (ESRI, 2020).

This study applied an object based supervised classification approach to all five Northwest Beach aerial images using ESRI ArcGIS Pro version 2.7.0 software for all imagery analysis within this research. This software was chosen based on licensing availability through Wilfrid Laurier University. In previous LULC research, Petrila (2015) and Liu et al., (2018) comparatively assessed the use of object-based image analysis for LULC using both example-based classification and rule-based classification, concluding that the example-based classification was superior to rule based classification as it proved to be a more accurate method as a result of reduced spatial heterogeneity at the object level. Object-based image analysis segments image by grouping pixels rather than creating single pixels. Instead, it generates objects with varying geometries (ESRI, 2020). Liu et al. (2018) proved that object-based analysis when evaluating land cover change, proved useful in meaningfully segmenting historical imagery and when tested on modern imagery, object-based classification performed better than pixel-based methods when configured with segmented imagery. This was proven through evaluating the separate classification methods on a series of historical and modern imagery to evaluate land cover change in river morphology (Liu et al. 2018). To further add, the use of object-based image analysis accompanied with digital photogrammetry and GIS analysis of

classification of land use on sand dune topography was completed by Miyasaka et al. (2016). A segmentation approach was used initially to extract features based on objects, grouping pixels that contain similar spectral characteristics into segments and represented by a set of attributes for classification. Image segmentation is the first step in the supervised object-based classification, extracting features from imagery based on objects. These objects are created by the image segmentation process where pixels in proximity and having similar spectral characteristics are grouped together in a segment. Prior to implementing the segmentation process, the original aerial imagery, once imported successfully into ArcGIS Pro 2.7 software, was subjected to a band extraction. The raster function “Extract Bands” tool in ArcGIS Pro was used to extract a 1,2,3 band combination from each of the aerial images, creating a true color composite using the red, green, and blue band combination. Band 1 with a wavelength of 0.45-0.52u m is capable of differentiating soil and rock surfaces from vegetation and detecting cultural differences. Band 2 with a wavelength of 0.52-0.60u m covers the reflectance peak from leaf surfaces, it has separated vegetation from soil. In barren lands, urban areas and roadways appear brighter while vegetation appears darker. Band 3 with a wavelength of 0.63-0.69u m senses in a strong chlorophyll absorption region and strong reflectance region for most soils, discriminating vegetation and soil. This band is able to separate croplands with standing crop from more barren area (Quinn, 2001). The central wavelength of the red band being 660nm, green band being 550nm and the blue band being 470nm. Original aerial imagery files were imported into this tool function while a .tif saved raster file was exported from the tool following process. Next, the image segmentation process was performed using the “Segment Mean Shift” tool found in the “segmentation and classification” image analyst toolbox in ArcGIS Pro. As previously stated, the image analyst “Segment Mean Shift” tool groups adjacent pixels into

segments that have similar spectral characteristics. The technique uses a moving window that calculates an average pixel value to determine which values should be included in each segment (ESRI, 2020). As the window moves over the image, it iteratively recomputes the value to make sure that each segment is suitable. The result is a grouping of image pixels into a segment characterized by an average color (ESRI, 2020). The 1,2,3 band combination .tif imagery saved previously was the raster image used as the input file for the segment mean shift tool function. A spectral detail of 18 was selected for this function, as a high value closer to 20 is appropriate when there are features to classify separately that have similar spectral characteristics (ESRI, 2020). A spatial detail of 3 was selected for this function, as a smaller value further from 20 creates spatially smoother outputs (ESRI, 2020). The results of additional values including higher spatial detail, and lower spatial detail were assessed and used to ultimately incorporate the values previously mentioned. The segmentation tools processing time and the associated hardware capabilities were additionally considered when selecting appropriate spectral and spatial value settings. The tool ran with the segment mean shift image output file being saved as .tif format.

As the classification method performed in this research is a supervised classification, the outcome of the classification depends on training samples that are provided. Training samples are representative for all the classes associated with the Point Pelee National Park Northwest Beach imagery. Supervised image classification identifies spectrally similar areas on an image by identifying training samples of known targets and then extrapolating those spectral signatures to other areas of unknown targets. As with Nayak (2018), classifications were based on the Ecological Land Classification (ELC) system for Southern Ontario, the standard classification

system that was used within the Land Use Land Cover Classification (Table 3.2). A classification schema was created based on ecological land cover class types identified by Nayak (2018) which was influenced by the original land classes identified by Dougan and Associates (2007). A classification schema determines the number and types of classes to use for the supervised classification being performed. The classes identified within the land use land cover classification is as follows, summarized in Table 3.2.

Sand barren and dune types (dune associated species) were differentiated throughout each of the imagery between sand barren and dune (grasses) and sand barren and dune (red cedar treed sand dune), as sand barren dune types were mainly dune grasses and other associated species while red cedar types consist of shrubs and trees. Sand barren dunes are the grasses and other species including beach grasses, Little Bluestem, Switchgrass, beach open graminoid, dry sand drop seed, wormwood etc. (Nayak, 2018). Sand barren and dune, Red Cedar treed sand dune type additionally includes hop tree (*Ptelea trifoliata*), choke cherry (*Rhus aromatic*), dwarf hackberry (*Celtis tenuifolia*) and Red Cedar (Nayak, 2018). Deciduous shrub thicket includes species such as common hackberry (*Celtis occidentalis*), white mulberry, black walnut (*Juglas nigra*) and white and black oak (*Quercus alba* and *Q. velutinna*). Shoreline type includes open shoreline with or without vegetation, ELC classified as sand open shoreline type (Nayak, 2018).

Scheduling availability for capturing aerial imagery resulted in imagery acquisition occurring during different seasons. The seasonal variability between imagery dates influences the accuracy of the LULC classification, specifically the total area occupied by specific land cover classes. A primary focus of the research is identifying the land cover change associated with past

management interventions. The seasonality differences between imagery are considered a minor influence on the study and the accuracy of LULC classifications. Vegetation dominated land cover classes are influenced by seasonality change through leaf-off conditions, impacting the amount of area occupied by the class. The deciduous thicket, cottonwood trees, and forest land cover classes are influenced by leaf-off conditions, resulting in a minor decrease in occupied area during fall and winter seasons and a minor increase in occupied area during spring and summer seasons. This imposes a minor influence on the occupied area of land classes located below the canopy of deciduous vegetation. During leaf-on conditions, the sand barren and dune, compacted sand and trail, and shoreline land classes occupy slightly less area as overhanging vegetation is classified as their respective land cover class. Additionally, seasonality changes influence the area occupied by the water land cover class with the fluctuating water level of Lake Erie, ultimately impacting the amount of area occupied by the shoreline land cover class. The seasonality variation is considered a limitation of the research and does not influence the overall accuracy of evaluating LULC change associated with past management interventions at Northwest Beach. Specifically larger scale changes between sand barren and dune (grasses) and deciduous thicket land classes.

Table 3.2: Land use land cover classes identified in research classifications for each of the five time designations

LULC Class	April 2017, May 2019, December 2019, September 2020, November 2020
	Land Cover Classes
1	Sand Barren and Dune (Grasses)
2	Sand Barren and Dune (Red Cedar Treed Sand Dune)
3	Shoreline
4	Infrastructure and Facilities

5	Cottonwood Trees
6	Compacted Sand and Trails
7	Deciduous Thicket
8	Forest
9	Water

Using the updated classification schema with the land cover classes identified above (Table 3.2), training samples were collected for the purpose of gaining the range of spectral signatures associated with each specific class. The image classification process uses the training samples, saved as a feature class, to identify the land cover classes in the entire image (ESRI, 2020). Initially, training samples were collected with the use of in situ observations, photos and field notes that were recorded throughout each of the four data collection periods. Training samples were primarily collected in Zone B and Zone C based on the ability to access the research zones and limitations associated with active rehabilitation activity. Five to ten training samples for individual LULC classes, for each set of imagery, were gathered through field collection periods. Samples were collected based on the area occupied by the individual land cover class and the bordering area between classes. Associated notes were focused on discerning the classes that border each other from one another. The location of the initial training samples that were collected across Northwest Beach are in Figure 3.1. The process of gaining initial training samples was associated with a level of human error when interpreting and recording observations in field. The error involved in this process is considered a minor influence and does not impact the overall accuracy of the resulting LULC classifications and their ability to identify change associated with past management interventions. Introduction of human error is associated

with the accuracy of discerning specific land cover classes from another, specifically minor variation in segment border and area between classes. The in-field collection and verification of initial training samples is a limitation of the study and does not negatively impact the findings of this research in evaluating the influence of past management interventions. Each set of Northwest Beach imagery had an associated training sample file created with the use of the ArcGIS Pro Training Sample Manager tool. With the use of the previously created segmented images, additional training samples for each specific class were collected throughout all four research zones, primarily zone A and D, using the segment picker option within the training sample manager for each image. Training sample segments distributed throughout the research site were collected for each class to include the full scope of the spectral signature associated with each. Once samples of each class type were collected, samples were merged using the collapse function to create a singular sample class containing all selected segments and eliminating any duplicate samples. The training sample file was then saved as a separate file to be used in the image classification wizard.

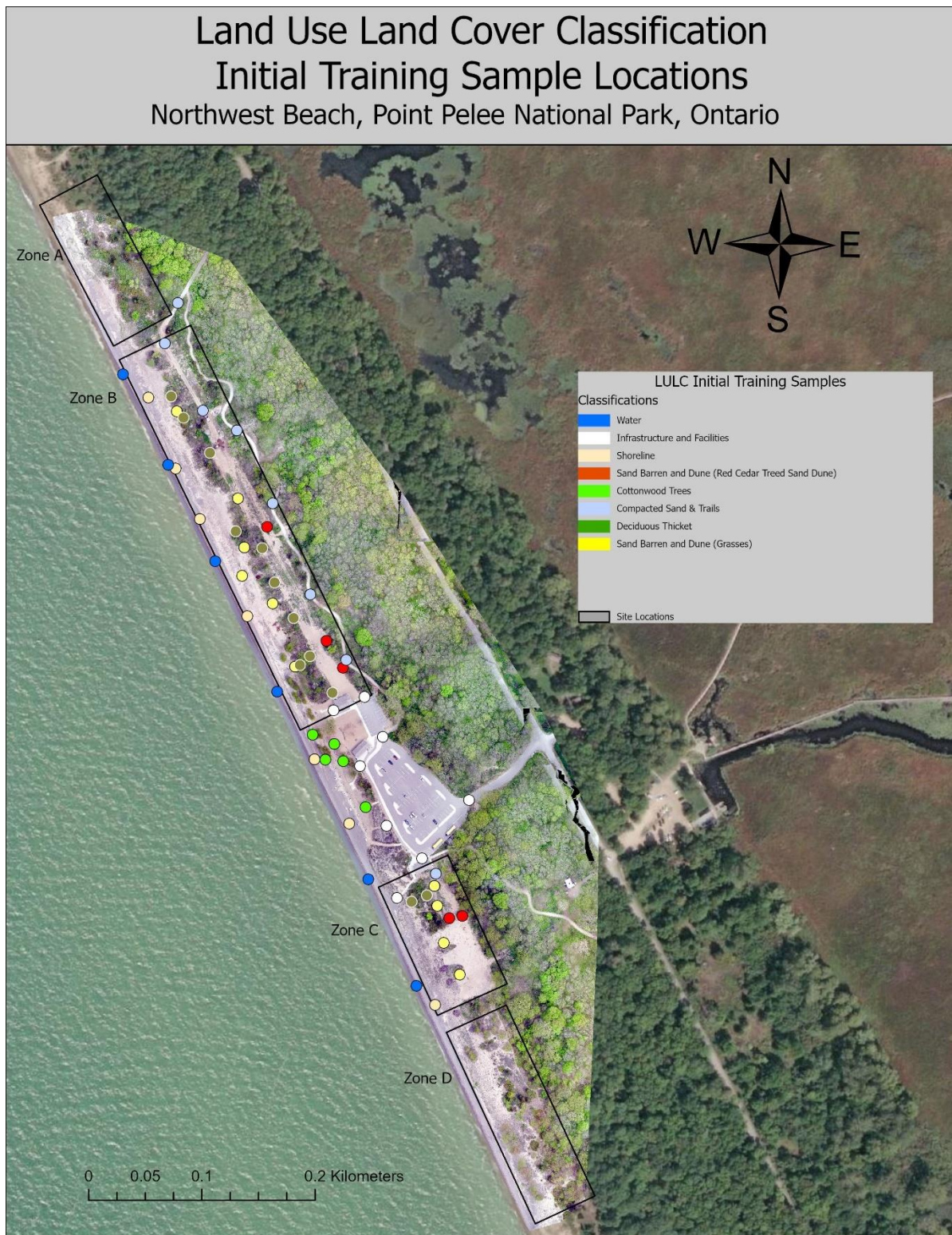


Figure 3.1: Map showing initial training sample locations of each land cover class throughout Northwest Beach, Point Pelee National Park.

Each of the five Northwest Beach images were then subjected to an object based supervised classification using ArcGIS Pro 2.7 classification wizard, found in image classification under imagery options tab. For each separate classification, the 1,2,3 extracted band images were selected to use with the classification wizard. First, the wizard was configured to perform a supervised classification method, using an object-based classification type, and importing the previously created classification schema used with training sample collection (Table 3.2). Within the optional configuration settings, the previously created segmented images were imported for each classification as well as the training samples for each image that were collected in the previous steps. The training sample manager menu within the classification wizard was not altered from the original training samples imported into the wizard. To train the imagery, the random trees classifier was selected as the method for classification. The random trees classification type was chosen over the other classification type options based on the methods ability to correct for the decision trees propensity for overfitting to training sample data, as well as its ability to accurately classify segmented imagery. The random trees classifier is an advanced machine learning technique that is resistant to overfitting and works well with segmented images as well as multispectral imagery (ESRI 2020). The random trees classifier will perform classification based on the input training sample file originally imported into the classification wizard. The random trees classification method is a collection of individual decision trees in which each tree is generated from different samples and subsets of the training data (ESRI, 2020). For every pixel that is classified, a number of decisions are made in rank order of importance. This method is classifying the dataset a number of times based on a random subselection of training pixels, resulting in many decision trees (ESRI, 2020). The default random trees classification settings were used, with maximum number of trees being 50,

maximum tree depth of 30 and maximum number of samples per class being 1,000 while the segmented attributed selected were “active chromatically color”, and “mean digital number”. These parameters were chosen based on the software’s recommended default settings and for its accuracy when compared to results of running a variation in the settings, involving smaller and larger tree depth, half, and double the amount of max samples. Once the classification wizard finished running successfully, the reclassifier tool was the last step before the supervised classification was completed. The reclassifier tool allows edits to be made to individual features or objects in classified imagery. This is considered a post-processing step designed to account for errors in the classification process. The current class and new class identified for reclassification are selected with both the “reclassify an object tool” and “reclassify within a region tool” being used to identify specific objects within the classified imagery and reclassify them to their correct class. The final output of the supervised object-based classification was subjected to a boundary clip that fitted all five images to the same extent and saved as a .tif output file.

Figure 3.2 shows a workflow diagram depicting the previously described methodology used in the aerial imagery classification process. The workflow diagram shows the primary methodology used to obtain the classified imagery in this research, identifying specific steps and tools implemented. Figure 3.2 details classification steps from pre-classification, object-based supervised classification, ESRI ArcGIS Pro classification wizard and the post-classification methodology.

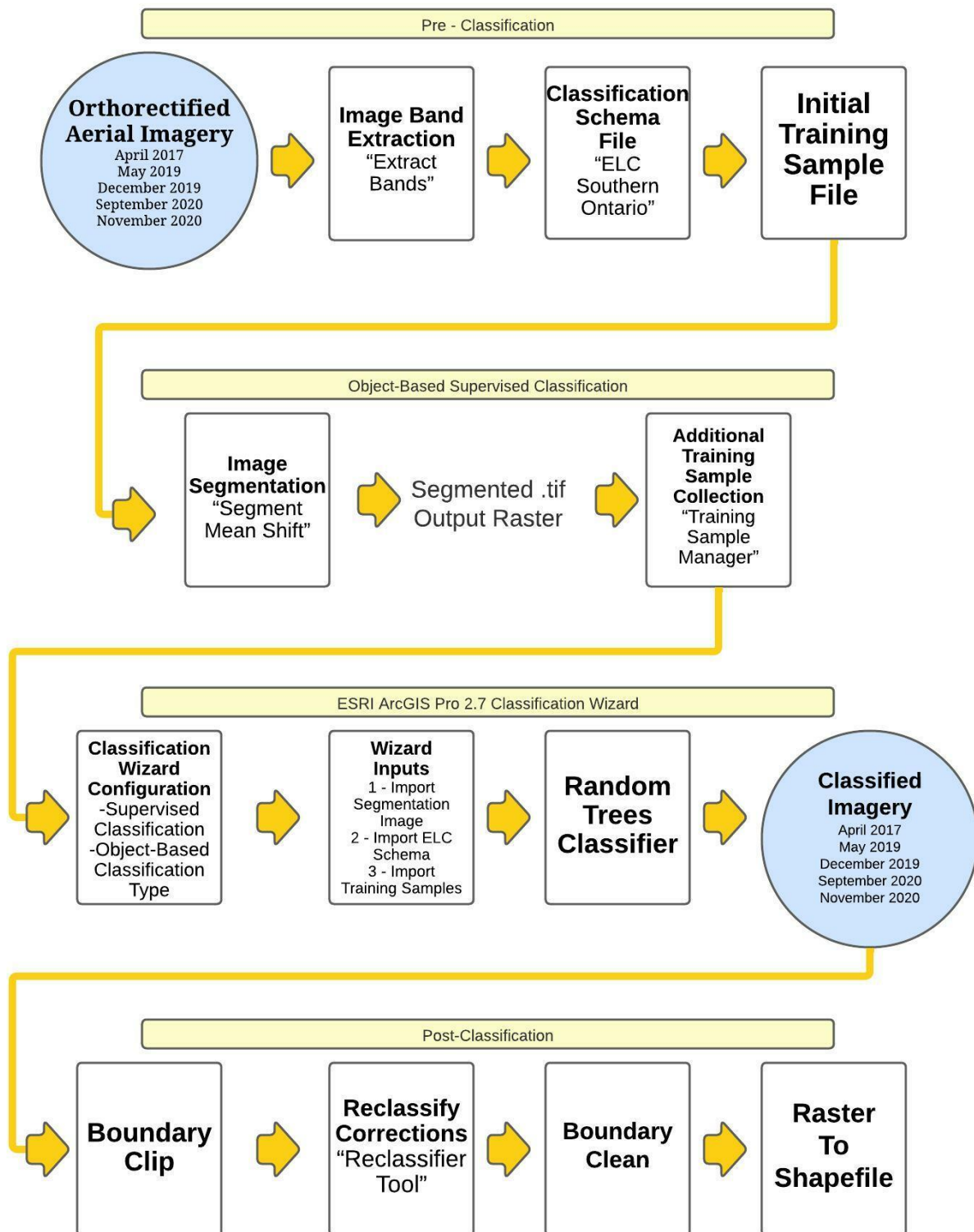


Figure 3.2 Workflow diagram showing methodology used in aerial imagery classification. Workflow diagram depicts steps used in classification process from pre-classification to post classification

Five LULC classification figures were created in total with classifications associated with the imagery dated from April 2017, May 2019, December 2019, September 2020, and November 2020. The “zonal geometry as table” tool in ESRI Arc Pro software was used to calculate the area in square meters (m²) that each of the LULC classes occupied throughout the Northwest Beach study site for each of the five-time designations. ESRI 2020 describes the zonal geometry to table tool as a tool that calculates the geometry measures (area, perimeter, thickness, and the characteristics of ellipse) for each zone, in this case LULC classes, in a dataset and reposts the result as a table. Each of the five LULC classifications were the input raster for the tool with the zone field being the associated LULC classes and the processing cell size automatically being generated by the tool reading the input raster file. Each of the created LULC classifications were calculated to have a total area of roughly 73,070 m². The total area associated with each LULC classification was used to calculate the area percentage (%) that each LULC class occupied at the corresponding time.

$$\text{Percentage of Area Occupied by LULC Class (\%)} = \frac{\text{Area Occupied by LULC Class (m}^2\text{)}}{\text{Total Area (\sim 73070 m}^2\text{)}} \times 100$$

Located in Chapter 5, a table depicting the area percentage associated with each LULC class at the corresponding time was used to identify the area for each class that experienced change throughout time, between each of the classifications (Table 5.6) and a figure detailing the change that occurred in each class (Figure 5.8). Specific areas and zone locations at Northwest Beach that experienced change in land use and land cover were observed and identified for each of the five classifications.

3.3 Five-lined Skink Population Abundance & Distribution

3.3.1 Point Pelee Five-lined Skink Monitoring Data Set

From 1998 to 2020, Point Pelee National Park collected a total of 3,930 five-lined skink abundance sightings over the span of 23 surveys (Parks Canada 2018). Using the census data collected during these surveys, 17 permanent quadrats, each 1 km in length, were established along the park's beaches on both the east and west sides (Figure 3.3). The quadrats were stratified into high, medium, and low based on the density of skinks observed during these surveys (Parks Canada, 2018). Three of the quadrats were removed from the sampling design due to time and access constraints, however, these quadrats contained such a low percentage of the population (1.6%) that their exclusion was not expected to significantly impact population estimates (Parks Canada, 2018). Beginning in 2015, all the high-density quadrats are sampled every year, along with 2 medium and 2 low quadrats (n=10), so that all quadrats are sampled every 2 years (Parks Canada, 2018).

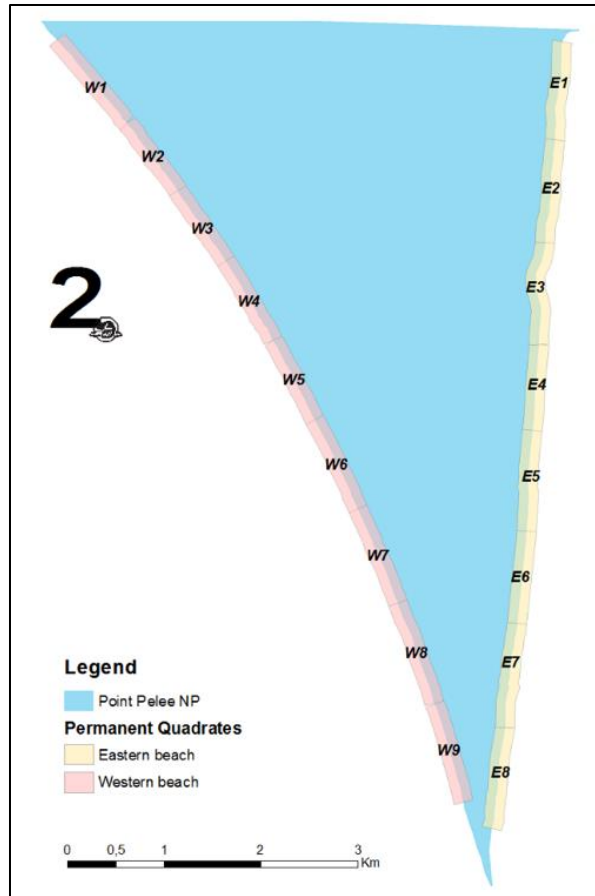


Figure 3.3: Map depicting five-lined skink monitoring quadrats (Parks Canada, 2018). Located on east and west coast of Point Pelee National Park (Parks Canada, 2018). Locations of quadrats utilized when conducting and documenting annual Parks Canada five-lined skink monitoring program.

Quadrats were surveyed during the same time each year (late June – early July) during the peak of nesting activity. Quadrats were sampled by walking along the beach through the stabilized dune and cedar savannah habitats, checking under all woody debris and counting the total number of skinks and nests observed (Parks Canada, 2018). Exact easting and northing locations of sighting, age class, sex, decay class of the woody debris and number of eggs in each nest were also recorded (Parks Canada, 2018). Point Pelee National Park was able to determine the condition of the skink population by estimating the average abundance of skinks during the five - year monitoring period (1998 – 2002, 2003 – 2007, 2008 – 2012, and 2013 – 2017). The trend was assessed by comparing the 80% confidence intervals between the period in question

and the previous period, where non-overlapping confidence intervals would indicate no change in abundance (Parks Canada, 2018). The comparison in skink abundance between varying monitoring periods can be seen in Figure 3.4

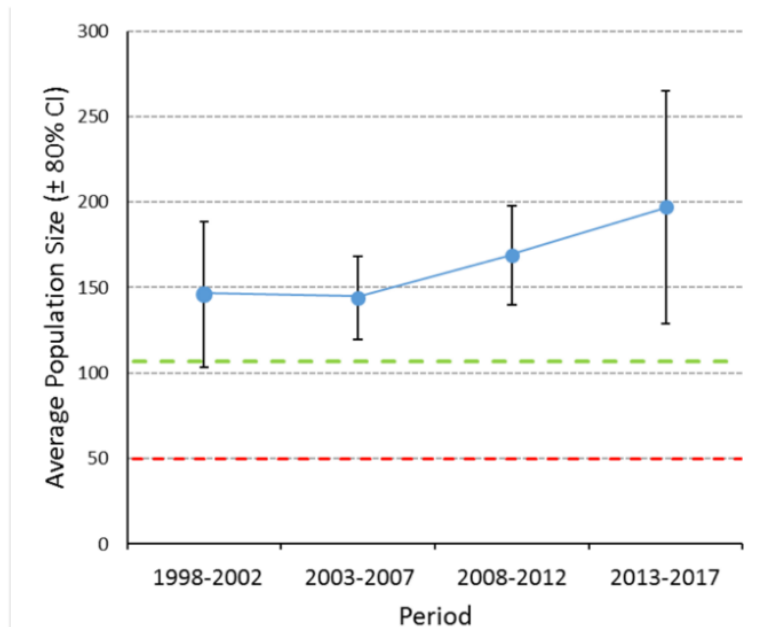


Figure 3.4: Average skink population size during each of the four 5-year monitoring periods (Parks Canada, 2018). All periods show a total population census (all quadrats sampled), except for 2013 – 2017, where 2015-2017 were populations estimates. Black error bars indicate the 80% confidence intervals. Dashed green-line and red-line show the Good-Fair threshold and Fair-Poor threshold, respectively (Parks Canada, 2018).

The skink abundance monitoring dataset is documented in an excel spreadsheet format including all the associated information previously mentioned. As the five-lined skink population in Point Pelee National Park is a federally listed endangered species, the contents of the abundance monitoring dataset are considered very sensitive data. The dataset, including the specific GPS tracked point location information for each sighting, could present problematic outcomes for the species if conveyed in the wrong manner or released for open access in its entirety. The sensitivity of the dataset, including the specific location data for individual sightings throughout the park, was taken into serious account throughout the research study.

Incorporation of the dataset into this research was done extremely carefully with the health and safety of the endangered species being at the forefront of all decision-making processes throughout the study. Methodology associated with the spatial interpretation of the five-lined skink population at Northwest Beach, Point Pelee was carefully constructed on the basis that exposure of specific location data associated with the species could lead to detrimental impacts on the population within the park. Specific methodology that could have been incorporated in the research but was avoided because of the sensitivity of the dataset is described in following sections.

3.3.2 Spatial Interpretation of Skink Distribution Methodology

As this study was designed to identify relationships and influences from the physical landform change and species distribution, it was important to focus on geomorphological influences rather than focusing on individual species tendencies displayed by the local skink population. ESRI ArcGIS Pro software was used to apply the GPS collected location data to a spatial representation in relation to the four research zones at Northwest Beach. Prior to the use of GIS software, the species dataset collected by PPNP ecologists was further refined in Microsoft Excel formatting the data to suit ESRI ArcGIS Pro spatial data requirements. Within Excel, the dataset was refined to include the following aspects of the original dataset: date, easting, northing, and total skinks. By including this information along with the spatially plotted location data of the skink sightings, identification of relationships with the physical landform change could be performed accurately.

Formatting the species data initially included separating the individual skink sightings point data based on the collection date year and grouping them in relation to the time series assigned to the land use land cover classifications depicting landform change. This included removing the few outliers from the dataset that did not include an accurate GPS recorded easting and northing location as well as any sightings with a recording of 0 for total number of skinks. The easting and northing data associated with each point was converted from the UTM coordinate system that was utilized in the original sighting recordings to the decimal degrees coordinate system. The conversion was performed using a downloadable Excel template designed to convert between geographic coordinates and UTM (GISCrack, 2017). The UTM to Decimal Degrees sheet was selected followed by transferring the sighting data to the appropriate “East” or “North” UTM columns. After selecting the WGS84 datum, zone of 17 and northern hemisphere, the coordinates were converted accurately. The original coordinates were converted to a decimal degree format as it is the desired unit of measure for ESRI ArcGIS software, imported as latitude and longitude. The X coordinates measuring longitude, the distance in degrees east or west of the prime meridian and Y coordinates measuring latitude, the distance in degrees north or south of the equator.

After formatting the species file, all cells containing required information for the study were selected and copied to a separate excel spreadsheet, separating time series categories by assigning each to separate excel sheets within the updated file. To add the updated species data within ESRI ArcGIS Pro, the tools tab was located and then add data were selected, and the option to add X and Y data was chosen, importing the updated species data set. The imported data table was then selected and displayed as X and Y data. Each sheet within the Excel file associated with a separate year designation is displayed separately from one another within Arc Pro. The

coordinate system associated with the imported data set was checked and updated by selecting edit under the table options and opening the spatial reference properties dialog box. After opening the geographic coordinate system directory, world folder was opened and WGS_1984.prj was selected as most frequently, especially in this specific research study, GPS data are collected on the WGS 1984 datum (ESRI, 2019). After defining the projection, the spatial reference was selected to add XY data so that the points are drawn in Arc Pro. The XY table to point geoprocessing tool was opened where the skink species file was set as the input table and the X and Y fields populated accordingly with the accurate location data.

Due to the sensitivity of the five-lined skink Monitoring Dataset and the species being listed as a species at risk in the COSEWIC registry, the way in which the location point data was portrayed spatially was crucial to the safety of the local population. Had the data been displayed inappropriately, resulting outcomes from the information being made publicly available could have been harmful to the population residing in Point Pelee National Park. At the discretion of the Parks Canada staff, the chosen methodology for this portion of the research was the most effective at both obtaining accurate results as well as protecting the local five-lined skink population. For this reason, the results of both objective 2 and objective 3 of the research could not include spatially plotted point data figures displaying specific locations of skink sightings across Northwest Beach or the National Park. Rather, the most effective alternative was to utilize the spatially plotted point data to record the variations in population distribution and convert the numerical recordings to a tabular format rather than a visual interpretation. Tables were created for each of the yearly time series designations, including population recordings for each of the four specific zones and a total for the corresponding year. With the use of Microsoft Excel software, separate scatter plots were

created depicting the variations in five-lined skink population located throughout Point Pelee National Park from 2014 to 2020, the population residing specifically at the Northwest Beach study site from 2014 to 2020, and the population residing in each of the four study zones (zone A, zone B, zone C, zone D) across Northwest Beach from 2014 to 2020. With the use of the corresponding scatter plots, variations in the five-lined skink populations over time, based on location, were compared to one another, for gaining the spatial interpretation of the population distribution and the comparative interpretation of the species distribution between four zones consisting of varying LULC compositions and management interventions. The preferred habitat composition of the skink population residing in Point Pelee National Park was determined. Descriptions pertaining to each of the four study zones at Northwest Beach follows in Chapter 4.

3.4 Coastal Landform Changes Influence on Endangered Five-lined Skink Population

3.4.1 Methodology

The third research objective focuses on comparatively assessing the local five-lined skink distribution and the LULC classification applied to the four zones located at Northwest Beach. This section focuses on the methodology associated with determining the coastal dune landform changes influence on skink population distribution and overall species abundance at Northwest Beach. Identifying the landform, land use and land cover change factors influencing local skink species distribution and overall species success allowed for the determination of the influence and overall success of past management interventions and rehabilitation practices that have been implemented at Northwest Beach. This leads into the overall goal of prescribing successful

rehabilitation measures for improving the Point Pelee National Parks five-lined skink population and restoring the natural ecosystem function at Northwest Beach.

Initially, the methodology involved merging the spatially plotted species distribution point data and LULC classification with one another, categorized by the designated time series and indicating the four research study zones. Specific methodology associated with the creation of the five LULC classifications was described in Chapter 3 Section 2, and specific methodology associated with determining the species abundance associated with Point Pelee National Park, Northwest Beach, and each of the four research zones located at Northwest Beach was described in Chapter 3 Section 3. The five-lined skink species point data, distributed spatially, and categorized by corresponding zone location, was used to calculate the species population abundance for each of the individual time series and zone locations to quantify the success of the species based on local geographic location. Five-lined skink population abundance data that were derived using ESRI Arc Pro software, were separated based on the associated time designations and displayed in tabular format, with each row associated with each of the four zone locations at Northwest Beach. The spatially interpreted species data were presented in tabular format due to the sensitivity of the data set with the five-lined skink being listed as an endangered species in the COSEWIC registry. The possible implications associated with presenting the species data in a spatially plotted manner was described in Chapter 3 Section 3. The resulting LULC classification maps overlaid with the tabular species abundance data provided the ability to interpret variations in skink population distribution based on their location in relation to the four zones and to identify the differences in landform change that influence the five-lined skink population distribution and overall species abundance.

Five figures were created in total, with each of the five LULC classifications overlaid with the associated skink species abundance tabular data and the four study zone locations across Northwest Beach. Figures were created for LULC classifications associated with imagery dated from April 2017, May 2019, December 2019, September 2020, November 2020. As the five-lined skink monitoring program was conducted on an annual basis between June and July of each year, LULC classifications for May and December 2019 were associated with the same 2019 skink abundance data while the September and November 2020 classification were associated with the same 2020 skink abundance data. As described in Section 3.2, the “zonal geometry as table” tool in ESRI Arc Pro software was used to calculate the area in square meters that each of the LULC classes occupied throughout the Northwest Beach study site for each of the five-time designations. Each of the created LULC classifications were associated with an area of roughly 73,070 m² in total. The total area associated with each LULC classification was used to calculate the area percentage (%) that each LULC class occupied at the corresponding time designation. A table depicting the area percentage associated with each LULC class at the corresponding time designation was used to identify the area for each class experiencing change throughout time, between each of the LULC classifications. Specific areas and zone locations at Northwest Beach experiencing change in land use and land cover were observed and identified for each classification. Along with changes in LULC class occupied area between time designations being identified, variations in five-lined skink population abundance and distribution throughout each of the four zones based on the associated time designations were also identified.

A comparison between each of the LULC class area percentages from April 2017 to November 2020 was conducted to identify the overall change in each land class that occurred throughout the three-year period. Comparing the earliest LULC classification, April 2017, and the most recent LULC classification, November 2020, areas of each zone that experienced change in occupied area of a specific land class were identified based on the percentage change between time periods. Additionally, a comparison between the 2017 and 2020 five-lined skink species abundance was conducted based on the distribution between the four zones at Northwest Beach. The change in total species abundance and the corresponding species distribution that occurred over the three-year period also being identified. This analysis is presented in the results section.

This methodology led to the determination of the coastal landform changes influence on the endangered five-lined skink abundance and distribution. The described methodology provided the ability to identify the relationship the endangered species has with the local land use and land cover and the influence that past management interventions and rehabilitation practices have had on the abundance and distribution of the skink population. By identifying the influence that past management interventions have had on landform change at Northwest Beach, and how that landform change has influenced the abundance and distribution of the skink population, accurate recommendations were made regarding future rehabilitation practices for the overall goal of improving the endangered five-lined skink population and restoring ecosystem function at Northwest Beach. Management recommendations were made based on mimicking or recreating as far as possible the natural conditions of the Northwest Beach coastal location to let nature primarily do most of the work (USACE, 2021).

CHAPTER 4

Research Study Site

4.1 Introduction

This research is specifically focussed on four zones (Zone A, Zone B, Zone C, Zone D) that are located at Northwest Beach study site of the western shore of Point Pelee National Park (Figure 1.4). The four zones selected for this research have been the focus of varying magnitudes of anthropogenic influence and rehabilitation measures throughout the history of Point Pelee, further emphasized in section 2.10. Parking lots located at Northwest Beach have been removed in stages beginning in 2007, in which one of the lots with comfort stations and bumpers was removed to rehabilitate lost dune habitat (Parks Canada, 2013). By 2014 additional stages followed, and by 2015 a new paved parking lot was installed, decreasing the overall parking footprint. In summer and fall 2019, recommended rehabilitation measures were implemented in the decommissioned parking area (Zone B) with more intensive practices introduced to support a local supply of sand. The heavily vegetated foredune was pushed over to supply local sand to support a natural regeneration of the dune habitat in this area. Proper measures were taken to ensure the local vegetation species within this area were safe throughout the rehabilitation process through potting and replanting practices, as described in section 2.10. The impact of this active management on these four zones resulted in changes in both land use and land cover that altered the natural coastal dune landform characteristics. The changes in dune morphology directly impact the habitats' ability to support local species populations. Species such as the endangered local five-lined skink depend on this coastal dune ecosystem, creating a relationship between the overall landform change within the coastal system and the way in which that change

impacts the species population distribution and abundance. The rehabilitation practices at Northwest Beach and continuous adaptations since the early 2000s have actively been attempting to return this coastal habitat to its natural landscape to support native species and species at risk.

4.2 Northwest Beach Zone A

Zone A consists of an area that remains in an impacted state, not having been subject to many management activities, but with a signature from anthropogenic activity in the park. Located north of the other three research zones, zone A has not experienced any direct restoration activity. Zone A contains a coastal dune landform system that has been developing because of artificial barriers that have trapped and accumulated sediment since their introduction to the area. In this zone, there is a cleared path with electrical poles present that were installed close to the tree line, running parallel with the western coastline. The presence of these power lines and associated poles imposes a slight impact on the natural dune system while the main factor responsible for the unnatural accumulation of local sediment and resulting impacts on the dune system is the associated path that is kept clear. This infrastructure and the impact it has on the coastal system have been a main topic of discussion for Point Pelee Parks management, leading to the decommissioning of them in 2019 and their eventual removal in the near future because a new hydro corridor has been installed beneath the main road into the park. Parks Canada (2020) noted that it is planned in the next few years that Parks Canada (PC) staff, contractors, Hydro One, and Bell will decommission 6km of above-ground infrastructure. Parks Canada (2020) stated that this project will serve to better protect natural/cultural resources and public safety over the long term by: (1) eliminating aging infrastructure that require significant

corridor maintenance in sensitive species at risk (SAR), savannah, forest, and dune habitats and archeologically rich areas, (2) reducing safety risk to visitors and PC staff/contractors around the corridor, and (3) restoring these decommissioned corridor areas to their natural conditions thereby improving important wildlife/SAR habitats throughout Point Pelee National Park. Parks Canada (2020) noted that there are 51 “coastal” hydro poles that run along the west side / beach / dune area of the park extending from just north of gateway to Northwest Beach. Three hydro poles run into the forest / dune area between Sanctuary and Northwest Beach. Most of the utility poles in the park are from the 1950s, with few from the 1960s, 1970s and 2010s (Parks Canada, 2020). Parks Canada (2020) stated that by decommissioning the no longer used power corridor within Point Pelee National Park will result in the natural regeneration of these impacted beach / dune / Lake Erie Sandspit Savannah / forest / field ecosystems. Due to the decommissioning, maintenance will no longer be required for this hydro corridor, meaning that access to corridor locations will no longer be necessary, which in turn decreases the potential impacts to the ecological integrity of these areas and will allow regeneration (Parks Canada, 2020). Parks Canada (2020) noted that this project is expected to have a long-term positive effect on the parks ecological integrity, vegetation communities, and species at risk (SAR). The experience gained from previous similar power line corridor project works / activities in PPNP, coupled with the knowledge and advice from various ecological, archeological, SAR specialists, herpetologist, and dune experts have resulted in well understood potential short-term effects of the removal project (Parks Canada, 2020).

4.3 Northwest Beach Zone B

Zone B is in an area currently being rehabilitated and was previously composed of a variety of infrastructure. Originally designed as a parking lot with washrooms and changing rooms, the area was decommissioned in 2007, leading to the removal of parking lot associated infrastructure such as concrete parking bumpers and gravel lane ways. This heavily impacted area of the Northwest Beach was designated an area of concern for rehabilitation measures and has since experienced varying habitat improvements (Figure 4.1). Located directly adjacent to zone A, zone B has been and is currently adjusting through an intensive ecosystem restoration process. In summer of 2019, Point Pelee staff began transplanting native coastal vegetation, and removing brush and invasive species from the area prior to the gravel sediment removal that previously enclosed the decommissioned parking lot. Next, with the use of construction machinery, parks staff pushed over the artificially stabilized dune that had accumulated in this area. The sand from the dune was spread across the previous parking area and sculpted to create a topography throughout the rehabilitation area that was like the natural distribution as if the artificially stabilized dune had not been there. Native species were then retransplanted into the rehabilitation area along with woody debris and logs to support native species populations

including the five-lined skink. The area continues to be regularly monitored by Parks Canada staff removing invasive species by hand pulling.



Figure 4.1: Before and after images of Zone B. These display the topography and vegetation cover of zone B prior (on the left) to any rehabilitation measures and following (on the right) the rehabilitation practices that were undertaken in fall 2019. Image on right displays the sculpting of sand to aid in creating natural dune habitat topography prior to the reintroduction of native vegetation.

4.4 Northwest Beach Zone C

Zone C was extensively rehabilitated beginning in 2008 and continues to receive ecosystem management to maintain its improvements in habitat conservation. It is located south of Zone B and adjacent to the most recently installed comfort station and parking infrastructure that is considered a sacrifice zone for Northwest Beach visitors. Originally consisting of parking infrastructure and a comfort station that extended parallel to the beach, zone C has been managed extensively. In 2000, the boardwalk along the south section of the parking lot was removed, followed by the decommissioning of the south comfort station and the remaining finger boardwalks and fence in 2007 and 2008 (Parks Canada, 2013). Following these removals, the southern two cells of the south end of the parking lot were blocked off to vehicles and the area was left to natural succession and sand movement (Parks Canada, 2013). According to Parks

Canada (2013), the restoration area is 5,606 m² in size located immediately south of the Northwest Beach exit lane, decommissioned fully in 2008. Parks Canada (2013) stated that as of 2013, the area contained compacted soil and gravel from the old parking lot and a heavily vegetated dune running along its western length. Remnant footpaths persisted through the foredune and back dune areas where boardwalk “fingers” existed to allow visitor access to the beach. Parks Canada staff rerouted visitor pathways and ensured that visitor traffic through this area was halted. Staff transplanted native dune species, leading to the accumulation of new sediment, and removing all non-native and invasive species from the area. Most Cottonwood trees were removed from the area, reducing the risk of a coastal squeeze shift in the habitat composition. Maintenance to the associated deciduous thicket was included in the management strategy to trap additional sediment that travelled past the initial foredune. Sand movement into zone C has been modeled after the undulating dunes in the model habitat in Zone D (Parks Canada, 2013). Active management practices have been maintained until present, ensuring native species dominate the landscape using consistent weeding and prescribed burning practices to ensure the coastal dune landform formation and habitat sustainability continues.

4.5 Northwest Beach Zone D

Zone D consists of an area exhibiting the most natural characteristics of the coastal dune landforms throughout Northwest Beach (Figure 4.2). Located the furthest south of the four zones, zone D is located directly adjacent to zone C and has been considered the model habitat to guide all rehabilitation practices for Northwest Beach. The natural area has had very little management activity conducted and contains a small footpath that hikers, birders, and butterfly

enthusiasts use to move through the area. There has not been any infrastructure present in this zone. It has been the model habitat, guiding management strategies throughout Northwest Beach as it exists in response to the level of sediment supply and wind conditions that naturally change the area. According to Parks Canada (2013) zone D is classified as Little Bluestem – Switchgrass – Beachgrass Open Graminoid Dune type and will guide the overall goal of the restoration project. This includes examples of desired foredune and back dune habitats with representative herbaceous and woody vegetation, and desired dune formations (Parks Canada, 2013). Ideally, once sand movement begins, a gradual transition of habitats, from beach, to marram grass to patchy shrubs to back dune habitat will be created in zones A, B and C, mimicking zone D.

Parks Canada (2013) describes the Little Bluestem – Switchgrass – Beachgrass Open Graminoid Sand Dune type at Northwest as having substrates that consist of unstable coarse sand with no soil horizon development. Towards the eastern forested dunes, the soils appear to be slightly enriched with organic material (Parks Canada, 2013). Aeolian processes dominate and, as such, large and sometimes extensive open sand patches are present. The foredune contains considerably less vascular plant diversity, and larger areas of bare sand, than the backdune (Parks Canada, 2013). The windward foredune is subjected to higher rates of sand erosion/accretion and is therefore limited to a few graminoid species (Parks Canada, 2013). The community forms two floristically distinct zones with differing species, depending on landscape position. The foredune is more unstable and is dominated by mono-specific stands of marram grass (Parks Canada, 2013). The backdune and the flat sand plain immediately adjacent to it, are dominated by a more diverse graminoid cover, including stands of little bluestem (*Schizachyrium scoparium*), switch grass, marram grass, sand dropseed (*Sporobolus cryptandrus*), nodding wild rye (*Elymus*

canadensis), Canada bluegrass (*Poa compressa*) and Muhlenberg's sedge (*Carex muhlenbergii*) (Parks Canada, 2013). In disturbed areas, Canada bluegrass is more dominant (Parks Canada, 2013). On the bare sand patches, sand dropseed and Muhlenberg's sedge are more evident. Overall, the Little bluestem consistently appears as the most dominant species in the backdune area (Parks Canada, 2013).

Parks Canada (2013) noted that herbaceous forbs dominating this area include wormwood (*Artemisia campestris ssp. caudata*), bouncing-bet, spring whitlow-grass (*Erophila verma*), spotted knapweed, sky-blue aster (*Symphyotrichum oolentangiense*), hoary false-alyssum (*Berteroa incana*), white sweet clover, and plains puccoon (*Lithospermum caroliniense*) (Parks Canada, 2013). Low shrubby species, as well as taller shrubs, become common in this community type as it integrates with shrub dominated community types toward the forested dune ridge to the east (Parks Canada, 2013). Parks Canada (2013) listed typical shrubs including common juniper (*Juniperus communis*), poison ivy (*Rhus radicans*), fragrant sumac (*Rhus aromatica*), riverbank grape (*Vitis riparia*), common hoptree (*Ptelea trifoliata*), chokecherry (*Prunus virginiana*), and rough-leaved dogwood (*Cornus drummondii*). Scrubby black oak (*Quercus velvutina*) and red cedar (*Juniperus virginiana*) saplings are also present (Parks Canada, 2013).



Figure 4.2: Images showing the habitat composition present in zone D, Northwest Beach. Imagery displays the Little Bluestem – Switchgrass – Beachgrass Open Graminoid Sand Dune Type with species present such as strands of little bluestem (*Schizachyrium scoparium*), switchgrass, marram grass and sand dropseed (*Sporobolus cryptandrus*). Note the naturally occurring patches of open sand. Image's courtesy of Dr. M-L Byrne.

CHAPTER 5

Results & Discussion

5.1 Introduction

This chapter focuses on identifying the influence that coastal landform changes at Northwest Beach, Point Pelee National Park has had on the endangered five-lined skink species abundance and distribution. Northwest Beach has undergone numerous changes due to park visitor recreation, infrastructure development and decommissioning and recent management intervention implemented based on habitat restoration for improving ecosystem function.

Parks Canada has prioritized and is actively engaged in strengthening management strategies for efficient and productive restoration practices to address the endangered status of the five-lined skink (*Plestiodon fasciatus*). Restoration of the coastal habitat including the sand dunes at Northwest Beach in Point Pelee National Park is an ongoing process that began with the decommission of parking lot infrastructure in 2007. In fall 2019, management interventions included altering the heavily vegetated and artificially stabilized foredune, while preserving the native species and removing invasive species. The artificially stabilized dune was then pushed landward, and the sand redistributed throughout the former parking lot area followed by native species being replanted throughout the area. The focus of this research is to determine the success of this intervention at Northwest Beach and to inform and recommend future rehabilitation practices to improve overall ecosystem function for five-lined skink habitat. Since restoration is a long-term process, monitoring land use and land cover changes as well as outcomes of restoration activities is vital to progress toward ecological integrity.

This chapter includes three main sections, each including an individual discussion section of the results associated with the research objectives. The next section focuses on the first research objective, the analysis of land use land cover changes at Northwest Beach and the influence past management interventions had on landform change. The following section focuses on examining the abundance and distribution of the five-lined skink population at Northwest Beach and determining the desired and most suitable habitat for the species. The last section focuses on determining influence that coastal landform changes have had on the five-lined skink population abundance and distribution at Northwest Beach.

5.2 Results & Discussion

5.2.1 Land Use Land Cover Classification

This section addresses objective one of this research, analyzing the change in land-use and land-cover at Northwest Beach and the influence past rehabilitation practices have had on landform change by focussing on the spatial interpretation of the overall land use and land cover change across PPNP Northwest Beach, the spatial interpretation of past and current rehabilitation measures and the influence of rehabilitation practices on landform change. This section addresses the hypothesis that changes in land use and land cover focused on habitat rehabilitation has been impactful in returning the LESSS habitat at Northwest Beach to a natural habitat composition, primarily in dune development.

The destruction and modification of naturally occurring habitats due to land use change is one of the most immediate and important threats to biodiversity (Newbold et al., 2015). To assess any results or delayed results of dune restoration, it is essential to evaluate land use and land cover changes. Ruiz-Luna and Berlanga-Robles (2003) determined that changes in the natural ecosystem are driven by land use and land cover change, which is driven and accelerated by natural phenomena and anthropogenic activity. Bartholome and Belwad (2005) noted that remotely sensed imagery has been used extensively to generate a greater understanding of changing land surface characteristics and dynamics and monitoring land use and land cover changes. Observing changes in the LULC Classifications was an essential criterion for understanding the overall magnitude of landform change, the difference in landform changes between the four varying zones, and the influence that management interventions have had on landform development. The use of object-based image analysis accompanied with GIS analysis was completed by Miyasaka et al. (2016) studying the classification of land use on sand dune topography. Miyasaka et al. (2016) used high-resolution images to contribute to relevant policy and management planning in the past. Remote sensing data provide the capabilities to monitor a wide range of landscape properties important to management and policy, where information on these properties is needed in the past, present, and future (McVicar et al. 2003).

The following LULC classification maps were produced with the area of individual classes being calculated and presented in tabular format. Figures 5.1, 5.2, 5.3, 5.4, 5.6 provide LULC classifications for April 2017, May 2019, December 2019, September 2020, and November 2020 respectively. Refer to Tables 5.1, 5.2, 5.3, 5.4 and 5.5 for detailed LULC class areas of corresponding classifications.

April 2017 Land Use Land Cover Classification

Northwest Beach, Point Pelee National Park, Ontario

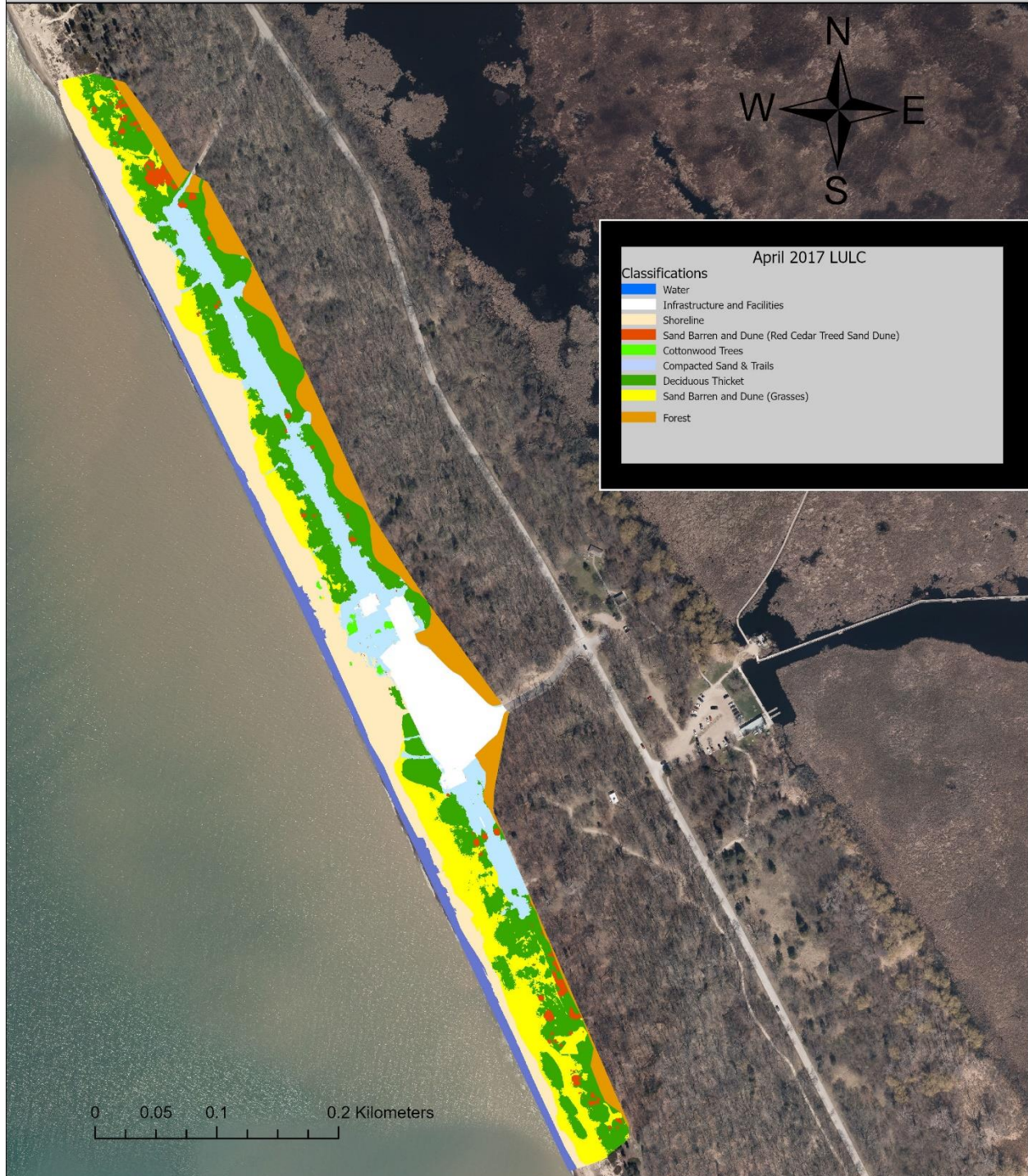


Figure 5.1: April 2017 land use land cover classification. Figure displays the earliest representation in this research of the composition of land use and land cover across the entire Northwest Beach study area.

Table 5.1: April 2017 land use land cover classification class area (m²) and area percentage (%)

April 2017	Class	Area in sq. m (m²)	Area Percentage (%)
1	Water	3232.78	4.42
2	Infrastructure & Facilities	7346.058	10.05
3	Shoreline	14264.28	19.52
4	Sand Barren & Dune (Red Cedar Treed Sand Dune)	1296.44	1.77
5	Cottonwood Trees	201.29	0.28
6	Compacted Sand & Trails	11690.13	16.00
7	Deciduous Thicket	23972.29	32.81
8	Sand Barren & Dune (Grasses)	11066.68	15.15
	Total	73069.95	100

Table 5.1 shows LULC class areas and the area percentages for Northwest Beach, Point Pelee National Park in April 2017. Eight classes were delineated according to the Ecological Land Classification System of Southern Ontario and the procedures followed in Nayak (2018). Despite forest and water being delineated because they were within the study boundary, the associated changes in these classes were not included as the research focus was the beach/dune area. In April 2017 deciduous thicket, shoreline, and compacted sand & trails were dominant LULC classes followed by sand barren and dune (grasses) being less prominent. The April 2017 classification shows that 16 % of the classified study area of Northwest Beach consists of compacted sand and trail totalling 11690 m². Much of this class, located in the back dune, east of the deciduous thicket, is associated with compacted sand where the decommissioned parking lot was in zones B and C following the infrastructure removal. The dominant LULC class from the April 2017 classification was deciduous thicket, totalling 23972.3 m² in size, 32.8 % of the classified area. The sand barren and dune (grasses) class was 11066.7 m² in size, accounting for 15.2 % of the classification area while the shoreline class was 14264.3 m², accounting for 19.5 %

of the classified area. In April 2017, the total area consisting of infrastructure and facilities at Northwest Beach was 7346.1 m², 10.1% of the classified study area.

May 2019 Land Use Land Cover Classification

Northwest Beach, Point Pelee National Park, Ontario

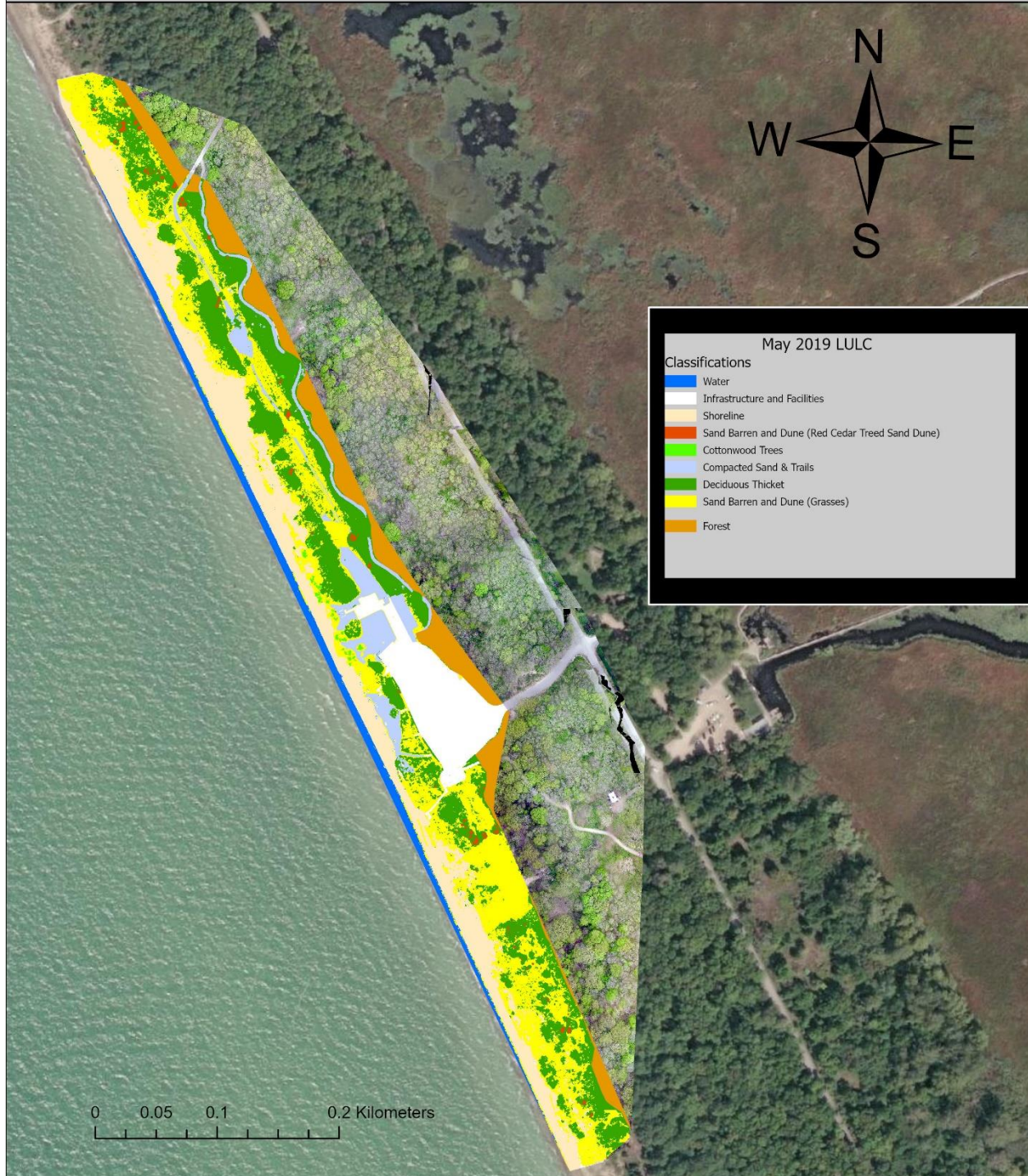


Figure 5.2: May 2019 land use land cover classification. Figure displays the compositions of land use and land cover across the Northwest Beach study area following rehabilitation recommendations made by Nayak (2018).

Table 5.2: May 2019 land use land cover classification class area (m²) and area percentage (%)

May 2019	Class	Area in sq. m (m²)	Area Percentage (%)
1	Water	1953.88	2.67
2	Infrastructure & Facilities	7288.06	9.97
3	Shoreline	14540.64	19.90
4	Sand Barren & Dune (Red Cedar Treed Sand Dune)	563.52	0.77
5	Cottonwood Trees	201.28	0.28
6	Compacted Sand & Trails	4871.91	6.67
7	Deciduous Thicket	23659.66	32.38
8	Sand Barren & Dune (Grasses)	19991.70	27.36
	Total	73070.65	100

The LULC class area and area percentage for May 2019 are displayed in Table 5.2. As with the April 2017 classification, forest and water classes were delineated in the study area but not included in the analysis. The eight classes associated with the LULC classification were the same in May 2019 as they were in April 2017. There were no major changes observed in the area occupied by infrastructure and facilities and cottonwood tree classes from April 2017 to May 2019. In May 2019, deciduous thicket was still the most dominant class at 23659.7 m², accounting for 32.4 % of the classified area, only a 0.4% change from April 2017. The sand barren and dune (grasses) became a more prominent class in May 2019 in areas of the backdune that were previously dominated by the compacted sand & trail class. Sand barren and dune (grasses) occupied 19991.7 m², 27.4% of the classified area, an increase of 12.25% from April 2017. Compacted sand & trails class was 4871.9 m² in size, accounting for 6.7 % of the classified area. The decrease in this class by 9.3% from April 2017 to May 2019 occurred primarily in the previously described back dune area of zone B and C that had been occupied by parking infrastructure. The shoreline class occupied 14540.6 m², 19.9% of the classified area

which is like the April 2017 shoreline being 19.5% of the classified area. There was a 1% decrease in sand barren and dune (Red Cedar treed sand dune) from April 2017 to May 2019.

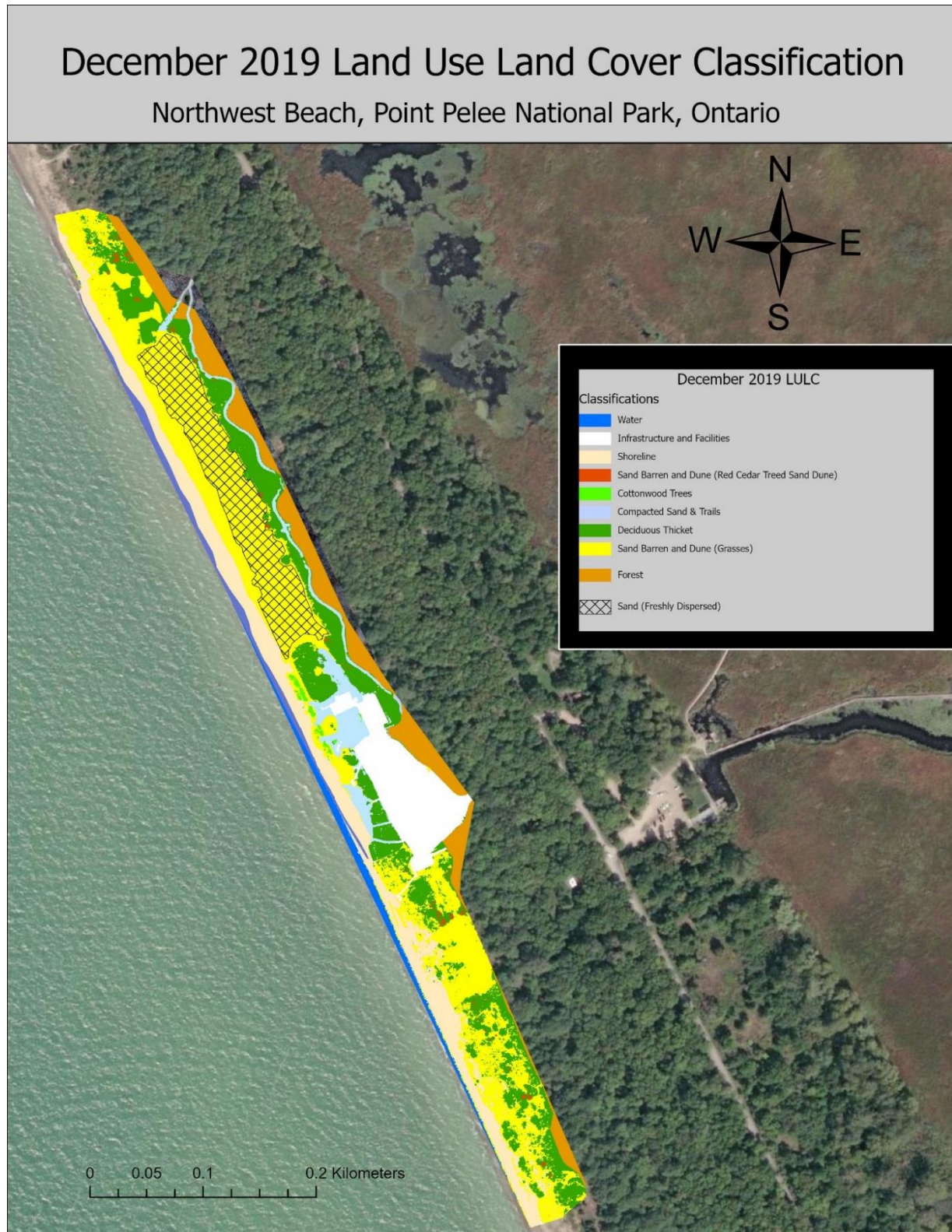


Figure 5.3: December 2019 land use land cover classification. Figure displays the composition of land use and land cover across the Northwest Beach study area following management interventions that were implemented in fall 2019. Area consisting of freshly dispersed sand is highlighted.

Table 5.3: December 2019 land use land cover classification class area (m²) and area percentage

December 2019	Class	Area in sq. m (m²)	Area Percentage (%)
1	Water	2307.41	3.16
2	Infrastructure & Facilities	7288.06	9.97
3	Shoreline	11662.78	15.96
4	Sand Barren & Dune (Red Cedar Treed Sand Dune)	163.86	0.22
5	Cottonwood Trees	246.01	0.34
6	Compacted Sand & Trails	4015.56	5.50
7	Deciduous Thicket	18948.37	25.93
8	Sand Barren & Dune (Grasses)	28438.11	38.92
	Total	73070.16	100

Table 5.3 shows the LULC classification class area and area percentage for December 2019. The same eight LULC classes were delineated in December 2019 as May 2019. There were no major changes observed in the study area for infrastructure and facilities and cottonwood trees from May 2019 to December 2019. The shoreline land class in December 2019 occupied 11662.8 m² (15.96%), a 3.9% decrease from May 2019 to December 2019. Sand barren and dune (Red Cedar treed sand dune) totalled 163.9 m² (0.22%), a decrease of 0.55% since May 2019. A minor change in the area occupied by this dune type land class. The compacted sand & trails land class in December 2019 occupied 4015.56 m² (5.5%), a small decrease of 1.17 % from May 2019. Most of the compacted sand & trails type at this time was located on the east side of Northwest Beach at the boundary of the adjacent forest, consisting of a walking path for visitors. The remaining compacted sand and trails type is surrounding the west side of the infrastructure and facilities at Northwest Beach. The second largest change in LULC classes area from May 2019 to December 2019 was observed in the deciduous thicket class. In December 2019, this class was 18948.37 m² in size (25.9%), a 6.5% decrease in deciduous thicket from May 2019.

This change was due to the change in the artificially stabilized foredune located in zone B, which was removed and replaced with native species. The rehabilitation practices and the associated change additionally coincided with a change in sand barren and dune (grasses) class. As detailed in Chapter 2, rehabilitation and restoration efforts in fall 2019 included pushing over the artificially stabilized foredune observed in April 2017 and May 2019 that introduced local sand to Northwest Beach, primarily in zone B. The sand barren and dune (grasses) class experienced the greatest change from May 2019 to December 2019. In December 2019, this class occupied 28438.1 m² accounting for 38.9% of the classified area. This was an 11.6% increase in sand barren and dune (grasses) class from May 2019 to December 2019.

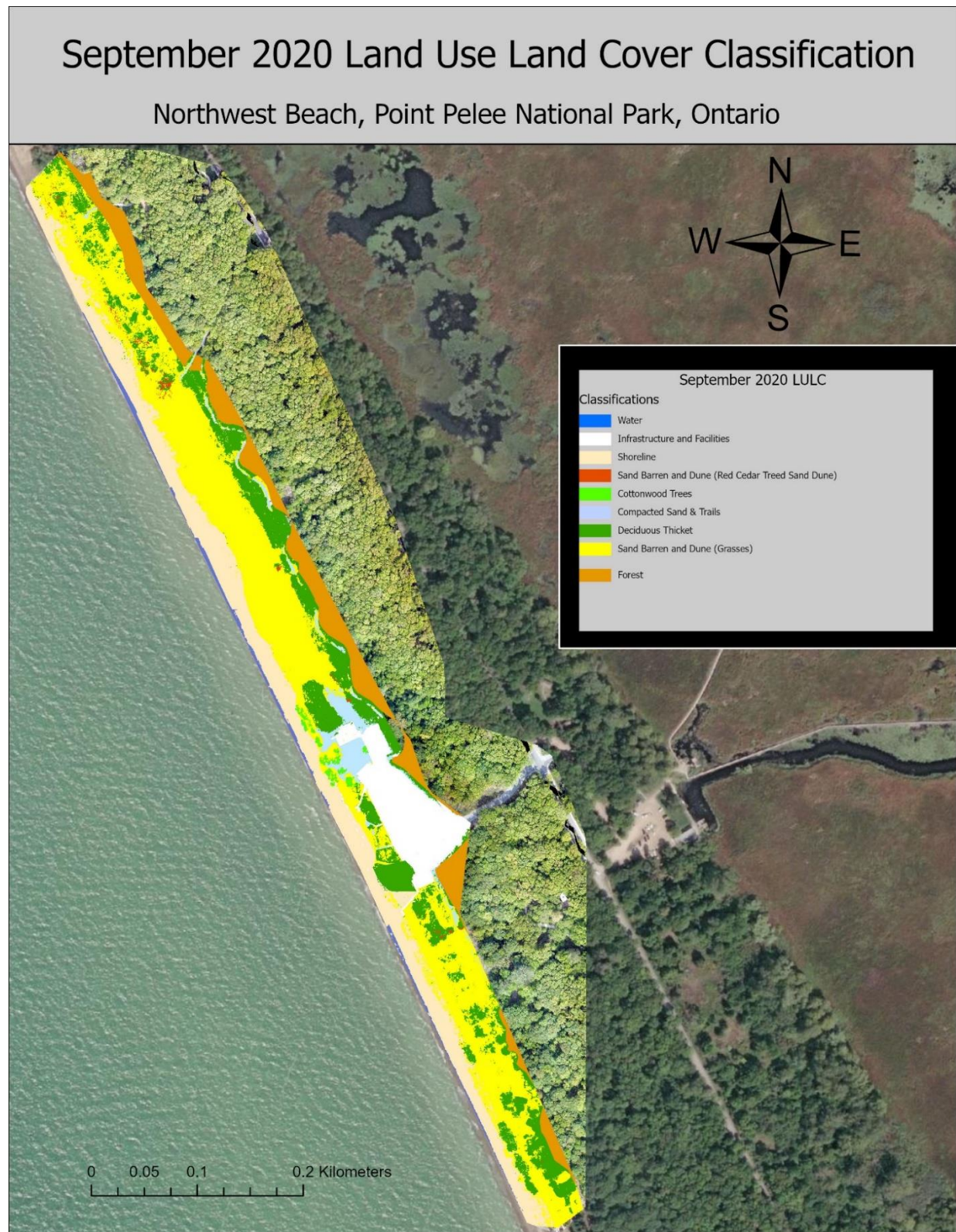


Figure 5.4: September 2020 land use land cover classification. Figure displays the compositions of land use and land cover across the Northwest Beach study area and the progression of changes following management interventions.

Table 5.4: September 2020 land use land cover classification class area (m²) and area percentage

September 2020	Class	Area in sq. m (m²)	Area Percentage (%)
1	Water	1030.54	1.41
2	Infrastructure & Facilities	7288.06	9.97
3	Shoreline	14235.56	19.48
4	Sand Barren & Dune (Red Cedar Treed Sand Dune)	258.69	0.35
5	Cottonwood Trees	246.00	0.34
6	Compacted Sand & Trails	2641.13	3.61
7	Deciduous Thicket	18274.82	25.01
8	Sand Barren & Dune (Grasses)	29095.35	39.82
	Total	73070.16	100

Table 5.4 displays the LULC classification class area and area percentage for September 2020. The same eight LULC classes were delineated in September 2020 as the first three LULC classifications. There were no major changes in the area occupied by infrastructure and facilities, sand barren and dune (Red Cedar treed sand dune), cottonwood trees and deciduous thicket land classes from December 2019 to September 2020. The shoreline land class in September 2020 occupied 14235.6 m² (19.5%), an increase of 5.4% from December 2019. The small variations in the shoreline classified area likely result from rising and falling water levels. The compacted sand & trails class in September 2020 occupied an area of 2641.1 m² (3.61%), a decrease of 1.9% from December 2019. Most of the compacted sand and trails class in September 2020 was the same size as the December 2019 classification with the small change taking place on the east side of the infrastructure and facilities between the shoreline and designated parking area. The sand barren and dune (grasses) class for September 2020 occupied 29095.4 m² (39.82), a small increase of 1% from December 2019 although the portion that was considered freshly dispersed sand in zone B in December 2019, was now classified as sand barren and dune (grasses). In

September 2020, in situ observations of the dispersed sand located in zone B concluded that dune grasses were now present such as marram grass species on the foredune adjacent to the shoreline (Figure 5.5).



Figure 5.5: Images showing native marram grass present on the foredune located in zone B of the Northwest Beach study site in September 2020.

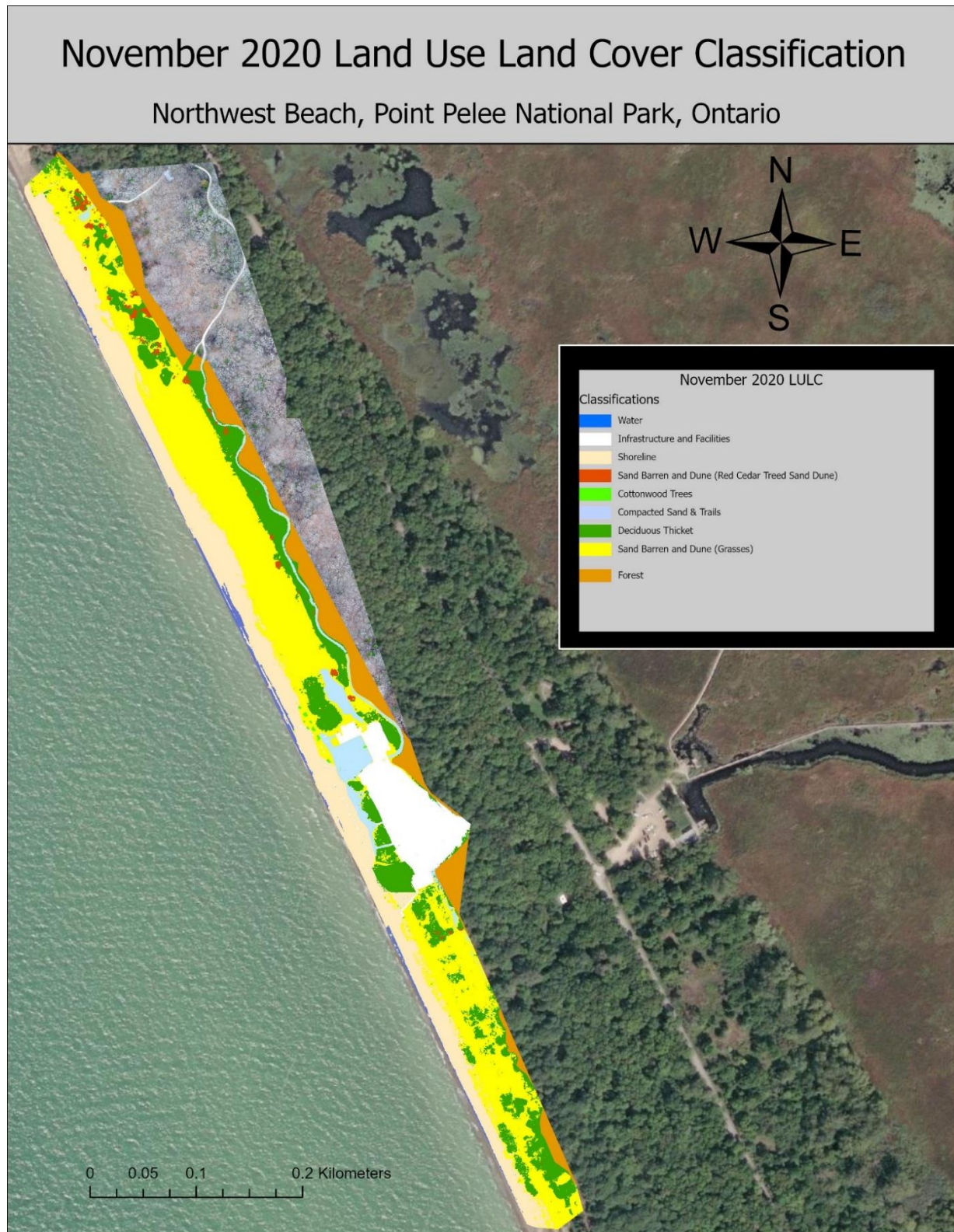


Figure 5.6: November 2020 land use land cover classification. Figure displays the most recent representation in this research of the composition of land use and land cover across the Northwest Beach study area and the land cover changes because of past management interventions.

Table 5.5: November 2020 land use land cover classification class area (m²) and area percentage

November 2020	Class	Area in sq. m (m²)	Area Percentage (%)
1	Water	674.64	0.92
2	Infrastructure & Facilities	7288.06	9.97
3	Shoreline	15108.75	20.68
4	Sand Barren & Dune (Red Cedar Treed Sand Dune)	362.20	0.50
5	Cottonwood Trees	71.34	0.10
6	Compacted Sand & Trails	3470.64	4.75
7	Deciduous Thicket	18082.41	24.75
8	Sand Barren & Dune (Grasses)	28010.30	38.33
	Total	73068.34	100

Table 5.5 shows the LULC classification class area and area percentage for November 2020. The same eight LULC classes were delineated in November 2020 as the previous four LULC classifications. There was very little change observed in any of the eight classes from September 2020 to November 2020. With minimal rehabilitation practices being implemented at Northwest Beach between these two time periods, there was very little change in land use land cover classifications. The shoreline class in November 2020 occupied 15108.8 m² (20.9%), a 1.4% increase from September 2020. The compacted sand & trails class occupied 3470.6 m² (4.8%), a 1.14% increase from September 2020. The sand barren and dune (grasses) class in November 2020 occupied 28010.3 m² (38.3%), a decrease of 1.49% from September 2020. In all other LULC classifications, there was less than 1% change in class area percentages from September 2020 to November 2020. Observations made in November 2020 indicated that dune associated grass species class such as native marram grass located on the foredune in zone B has increased in density (Figure 5.7).



Figure 5.7: Images showing native marram grass located on the foredune of zone B at the Northwest Beach study site in November 2020.

Table 5.6 shows the LULC class area percentages comparison between each of the five classifications performed in this research. The graph details the variation in the occupied area of each LULC class, by percentage, from the earliest classification, April 2017, to the most recent classification, November 2020. Table 5.6 shows the change that occurred in each of the LULC classes, throughout the Northwest beach study site, compared to one another based on the timeframe. The most prominent change to note from Table 5.6 is the change between May 2019 and December 2019 in which the Sand Barren and Dune (grasses) class surpassed the Deciduous Thicket class in becoming the most dominant in area occupied at Northwest beach.

Table 5.6: Land use land cover class occupied area percentage comparison between each LULC classification

LULC Class Area Percentages (%)	April 2017	May 2019	December 2019	September 2020	November 2020
Water	4.42	2.67	3.16	1.41	0.92
Infrastructure & Facilities	10.05	9.97	9.97	9.97	9.97
Shoreline	19.52	19.90	15.96	19.48	20.68
Sand Barren & Dune (Red Cedar Treed Sand Dune)	1.77	0.77	0.22	0.35	0.50
Cottonwood Trees	0.28	0.28	0.34	0.34	0.10
Compacted Sand & Trails	16.00	6.67	5.50	3.61	4.75
Deciduous Thicket	32.81	32.38	25.93	25.01	24.75
Sand Barren & Dune (Grasses)	15.15	27.36	38.92	39.82	38.33

5.2.1.1 Discussion

In April 2017, a dominant class of Northwest Beach land use and land cover composition was compacted sand and trail. This coincides with the management interventions that took place beginning in 2008 in zone C with similar interventions continued in 2014 in zone B. These management interventions consisted of the decommissioning and removal of parking lot infrastructure that led to compacted sediment and gravel materials being present in the decommissioned areas. This land cover type was classified as such in the April 2017 LULC classification. However, the most dominant LULC class during the April 2017 period was deciduous thicket, occupying 32.8% of the Northwest Beach study site. Large areas of deciduous thicket were observed on the foredune located on the west side of the parking cells of zone B and zone C. As prescribed by Parks Canada (2013) the portion of the vegetated foredune present in zone C had breaks created through it to aid in the natural sand movement and dune creation into the decommissioned parking areas. The April 2017 LULC classification results showed that the compacted sand and trail class dominated the decommissioned parking areas, along with deciduous thicket during this time, indicating the presence of barriers for sand movement despite the creation of breaks in the foredune. This illustrates that there was a restricted sediment supply to the parking areas as the sand continued to be trapped in the artificially stabilized dune.

Additional management interventions followed with the creation of larger breaks through the foredune in zone B and C along with invasive meadow vegetation removal and native dune species being planted in the decommissioned parking areas. The results of the LULC classifications show that by May 2019, the compacted sand and trails class had decreased by

9.3% in occupied area while the sand barren and dune (grasses) class increased by 12.25%. The change between these two land classes took place primarily in the decommissioned parking areas of zone B and zone C, suggesting that the larger breaks created in the foredune and the management of vegetation species had promoted the natural transport of sand into the decommissioned parking areas.

In fall 2019, native vegetation species that were present in the deciduous thicket, located on the foredune of zone B, were potted while invasive species were removed from the area. The foredune was then pushed over and the sand supply dispersed throughout the decommissioned parking area of zone B, introducing a localized supply of sand. The results of the December 2019 LULC classification showed a decrease of 6.5% in area occupied by deciduous thicket. This result coincided with an increase of 11.6% in area occupied by sand barren and dune (grasses). The increase in area occupied by sand barren and dune (grasses) took place primarily in zone B and was indicated as “freshly dispersed sand” that had previously composed the vegetated foredune prior to the management intervention. The change in land class and increase of sand barren and dune (grasses) is directly attributed to this management intervention implemented in fall 2019.

Native vegetative dune species were then planted in the freshly dispersed supply of sand throughout zone B. Woody debris obtained from nearby debris piles was dispersed randomly throughout the area to initiate local skink habitat. The September 2020 LULC classification results show that the fresh supply of sand was fully classified as the sand barren and dune (grasses) class as native dune species, such as marram grasses, expanded throughout zone B.

This result was maintained and displayed again in the November 2020 LULC classification with the sand barren and dune (grasses) class occupying 38.3% of the Northwest Beach study site.

The increase in area occupied by sand barren and dune (grasses) and the shift toward it being the dominant land class, indicates that the management interventions implemented in fall 2019 were successful. Parks Canada continues to monitor the rehabilitation process at Northwest Beach and implement practices involving vegetation species management when necessary.

5.2.2 Five-lined Skink Population Abundance & Distribution

This section addresses the second objective of examining the abundance and distribution of the endangered five-lined skink population and determining the most suitable habitat for the species based on the research at Northwest Beach by comparing the spatial interpretation of the five-lined skink population distribution throughout Point Pelee National Park with Northwest Beach. The key question examined was “is the five-lined skink population at Northwest Beach following similar abundance trends as the population across all of Point Pelee National Park and how evenly distributed is the population at Northwest Beach”. By evaluating the species distribution across Northwest Beach, the preferred habitat of the five-lined skink, based on the four zones of varying compositions, was determined.

The beach-dune habitat at Point Pelee supports several species at risk and rare species, including the endangered federally listed species under the SARA, the Five-lined skink (Parks Canada, 2013). The five Lined skink (*Plestiodon fasciatus*) that resides in the beach dune ecosystem in Point Pelee National Park (Parks Canada, 2013) is the only native lizard species in

Ontario. Parks Canada (2018) monitors the five-lined skink along the west beach of the park as an indicator of the health of the coastal ecosystem. The preferred habitat for this species has been improved over the past few decades through continued addition of woody debris and habitat restoration (Parks Canada, 2018). Parks Canada (2018) reported that the population of five-lined skinks at Point Pelee National Park has remained in good condition over the past 20 years of monitoring. Skinks at Point Pelee were experiencing a downward trend in the early 1990s attributed largely to disturbance and removal of woody debris by humans and illegal collection (Hecnar and Hecnar, 2013), however, according to Parks Canada (2018), the population improved after the park began increasing critical habitat by adding more woody debris to stabilize dune areas in 1995 (Parks Canada, 2018).

With the use of the Point Pelee National Park Five-Lined Skink Monitoring Dataset 1998-2020, populations for the entire park were grouped by corresponding year with total skink sightings for each year summed to obtain a total population value. Based on recorded easting and northing location data, skink sighting data points were plotted using ESRI Arc Pro software and clipped to the Northwest Beach study site. Sightings recorded in the study site were summed to determine a total population residing in Northwest Beach. Skink point data were clipped to the boundary of each individual study zone (zone A, zone B, zone C, zone D) and summed to obtain the five-lined skink populations located in each zone based on corresponding year. Skink sightings were plotted beginning in 2014 when larger scale rehabilitation measures began at Northwest Beach, until 2020, the most recent recorded sighting data. Descriptions of the corresponding rehabilitation practices can be found in Chapter 2, “Rehabilitation and Restoration Efforts”. Five-lined skink sightings in 2015 and 2018 were not included in the study as they were

not present in the Point Pelee National Park Five-Lined Skink Monitoring Dataset 1998-2020, a limitation of the dataset.

Figure 5.9 shows the variation in the recorded sightings of the five-lined skink population abundance from 2014 to 2020 throughout all of Point Pelee National Park. In 2014, the total recorded sightings of the five-lined skink in Point Pelee National Park were 258 skinks, the largest species abundance in the park since that year. Between 2014 and 2016, the recorded sightings of the five-lined skink decreased to 136, a decrease of 122 sightings over the course of two years. This trend continued into the next year as the recorded sightings in Point Pelee National park decreased to 91 sightings, the lowest recorded number of sightings in the seven years period being evaluated. This was an overall decrease of 167 recorded sightings in three years from its peak in 2014. By 2019, the number of recorded five-lined skink sightings increased to 224 throughout the park. This was an increase of 133 sightings in two years. This trend continued into the following year and by 2020, the most recent recorded period, the five-lined skink recorded sightings in Point Pelee National Park increased to 239 skinks, an increase of 15 skink sightings from the previous year. In 2020, there were 19 fewer sightings recorded than in 2014.

Figure 5.10 shows the variation in five-lined skink recorded sightings at Northwest Beach from 2014 to 2020. In 2014 the number of recorded skink sightings throughout Northwest Beach was 17. Between 2014 and 2016, the number of recorded five-lined skink sightings at Northwest Beach decreased to 15, a change of 2 sightings over the two-year period. This trend continued into 2017 with the number of recorded skink sightings decreasing to 13 throughout the

Northwest Beach study site. This was also a change of 2 sightings in the span of one-year and an overall decrease of 4 sightings since 2014. The number of recorded five-lined skink sightings at Northwest Beach in 2017 was the lowest recorded abundance in the seven-year period being evaluated. By 2019 the number of recorded five-lined skink sightings at Northwest Beach increased to 36, the highest recorded value in the seven-year period being evaluated. This was an increase of 23 recorded sighting abundance over the two-year period. This trend did not continue into the next year as the number of recorded sightings at Northwest Beach decreased to 25 by 2020. A decrease in recorded sightings by 11 in the one-year period. The number of recorded five-lined skink sightings at Northwest Beach in 2020 was 8 sightings more than the value recorded in 2014, an overall increase in the seven-year period being evaluated.

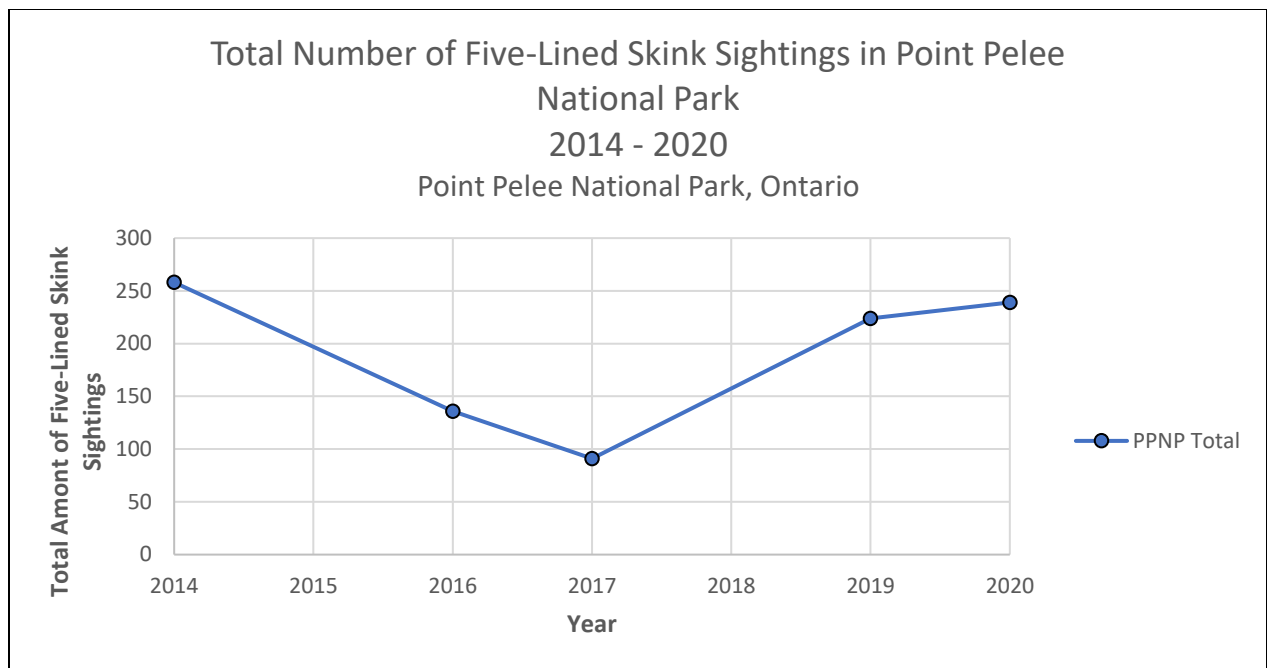


Figure 5.8: Point Pelee National Park variation in the number of recorded sightings of the five-lined skink population abundance from 2014 to 2020

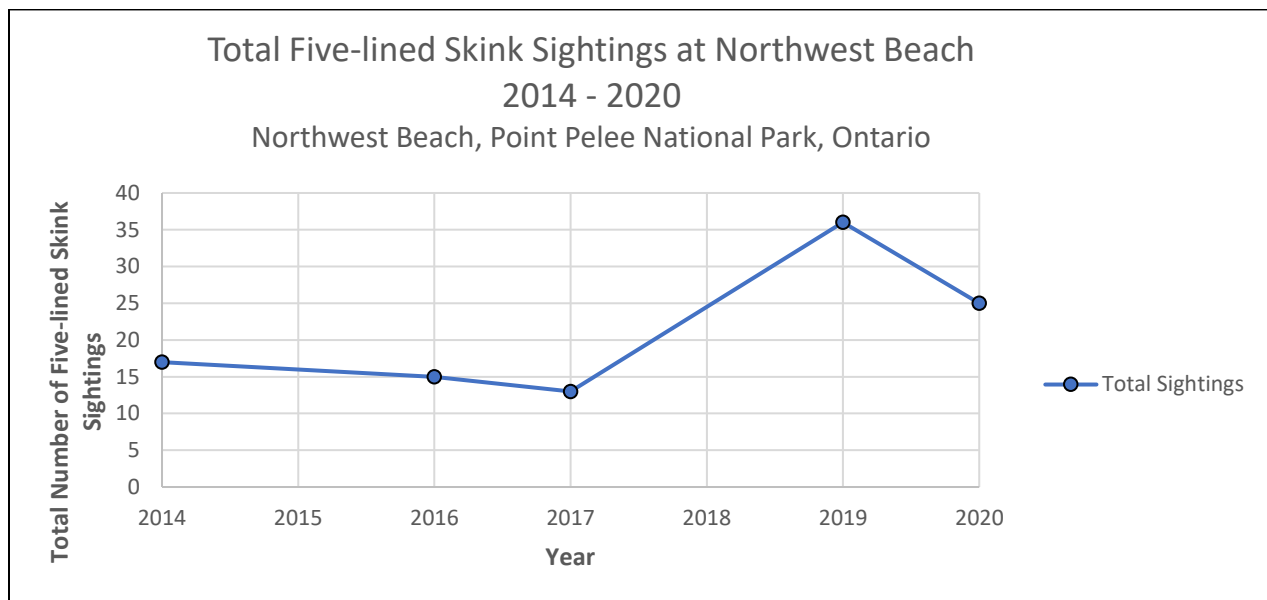


Figure 5.9: Northwest Beach study site variation in the number of recorded sightings of the five-lined skink population abundance from 2014 to 2020

Figure 5.11 shows the variation in recorded five-lined skink sightings at Northwest Beach based on specific zones as described in Chapter 4. In 2014, of the 17 total recorded sightings at Northwest Beach, there was 1 sighting in zone A, zero in zone B, three in zone C and 13 sightings in zone D. The percentage that each zone accounted for of the total sightings in 2014 was 5.9%, 0%, 17.6% and 76.5% respectively. Over the span of two years, the total recorded sightings at Northwest Beach in 2016 decreased to 15, zone A to 3 sightings, zone B to 0 sightings, zone C to 6 sightings and zone D to 6 sightings. The percentage that each zone accounted for of the total sightings in 2016 was 20%, 0%, 40% and 40% respectively. By 2017, with the total number of recorded five-lined skink sightings decreasing to 13, zone A reduced to 0, zone B to 0, zone C to 3 sightings and zone D to 10 sightings. The percentage that each zone accounted for of the total sightings in 2017 was 0%, 0%, 23% and 77% respectively. By 2019, the total number of recorded five-lined skink sightings at Northwest Beach increased to 36 sightings, the highest recorded value in the seven-year period being evaluated, with zero sightings in zone A, two in zone B, 18 in zone C and 16 sightings in zone D. The percentage that each zone accounted for of the total sightings in 2019 was 0%, 5.6%, 50% and 44.4% respectively. In 2020 the total number of recorded sightings at Northwest Beach decreased to 25 with five sightings in zone A, eight in zone B, five in zone C, and seven sightings in zone D. The percentage that each zone accounted for of the total five-lined skink sightings in 2020 was 20%, 32%, 20%, and 28% respectively.

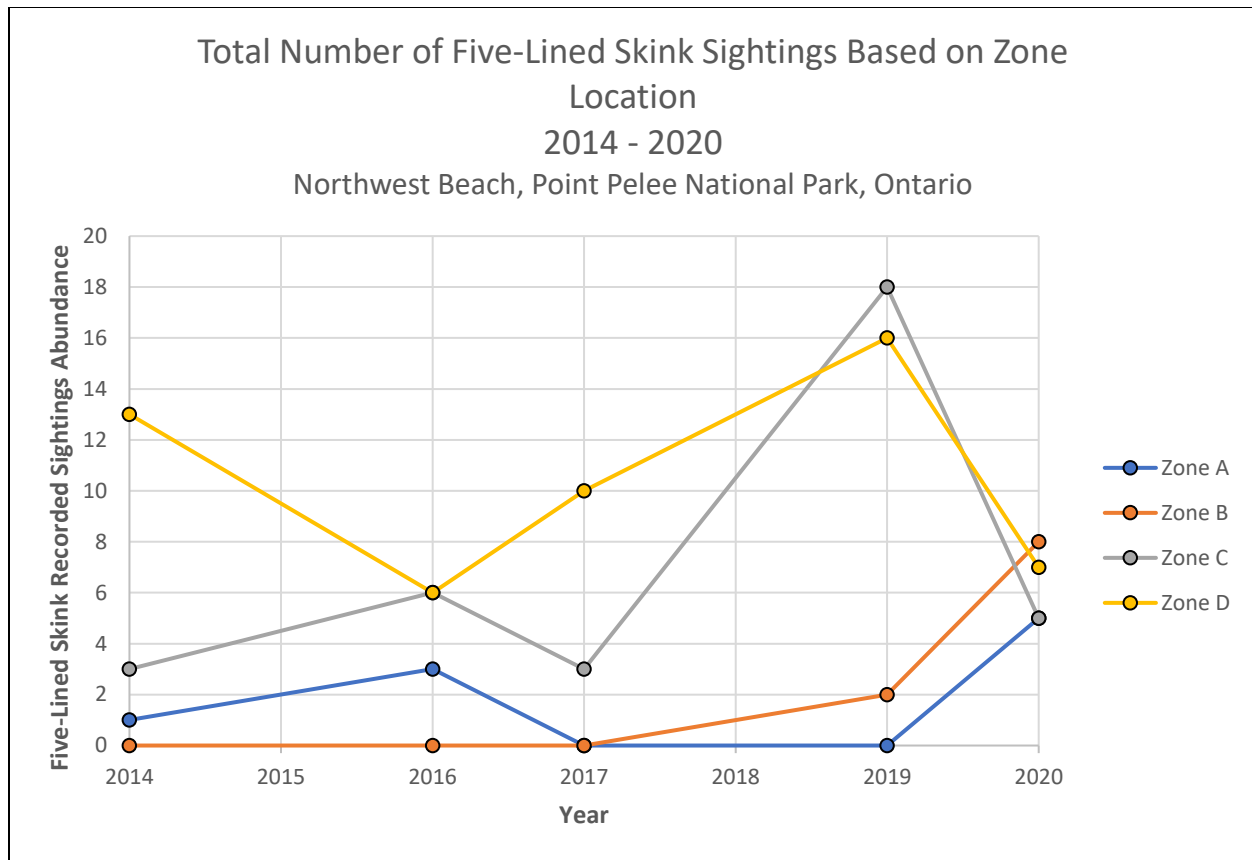


Figure 5.10: Northwest Beach variation between four research zones in the number of recorded sightings of the five-lined skink population abundance from 2014 to 2020.

5.2.2.1 Discussion

The portion of the five-lined skink population residing at Northwest Beach, and the entire five-lined skink population throughout Point Pelee National Park followed similar trends in the variation of the recorded sighting abundance. The total number of recorded sightings for the population at Point Pelee National Park decreased consistently from 2014 to 2017, a trend that was also observed in the Northwest Beach population. However, the number of recorded sightings throughout the park in 2014 was the highest number of annual sightings in the seven-year period being evaluated. This was not the case in the Northwest Beach population, where the

number of recorded sightings was 19 fewer in 2014 than the largest number of sightings, recorded in 2019. Both the five-lined skink population for Point Pelee National Park and the population at Northwest Beach experienced the lowest number of recorded sightings in 2017. By 2019, the next data year available, both experienced notable increases in the number of recorded sightings with the Northwest Beach population consisting of the highest number of sightings in the seven-year period. The following year, in 2020, the population throughout the national park continued the increasing trend of recorded sightings, nearly reaching its record high that was recorded in 2014. The population at Northwest Beach experienced a decrease but only falling to 25 recorded sightings, the second highest value recorded in the seven-year period.

While the Northwest Beach five-lined skink population consistently decreased in the number of recorded sightings from 2014 to 2017, most sightings were recorded in zone D, the most naturally occurring area in the study site, used to mimic the LESSS habitat composition. In 2014 zone D accounted for 76.5% of sightings, in 2016 it accounted for 40% of sightings and in 2017 it accounted for 77% of sightings. Of the 45 total recorded sightings between 2014 and 2017, just 4 were recorded in zone A and 0 were recorded in zone B. By 2019, the recorded number of five-lined skink sightings increased greatly at Northwest Beach, primarily in zone C. This coincided with management interventions in zone C that were recommended by Nayak (2018). The highest number of recorded sightings was in 2019, with the majority (18 sightings) being recorded in zone C while slightly fewer (16 sightings) were recorded in zone D. For the first time in the seven-year period, 2 sightings were recorded in zone B. This indicates successful management interventions took place at zone C prior to the 2019 skink monitoring program being conducted that were performed based on returning the area to the natural coastal habitat

composition, mimicking that of zone D. In 2020, slight declines in the number of recorded skink sightings coincided with intensive management interventions implemented in fall 2019 that involved changes to the land cover in zone B, large machinery within the study site and the intentional scaring of five-lined skink individuals from the area prior to management techniques being implemented for the safety of the species. This could have attributed to the lower number of recorded sightings. However, in 2020, the number of recorded sightings at Northwest Beach became more evenly distributed throughout Northwest Beach with zone A accounting for 20% of the recorded sightings, zone B accounting for 32% of the sightings, zone C accounting for 20% of the sightings and zone D accounting for 28% of the sightings. Once the park management began shifting zone C and zone B habitat composition through management interventions towards the natural habitat composition exhibited by zone D, the five-lined skink population in those areas began to expand in distribution and grow in abundance.

The preferred habitat of the five-lined skink, specifically at Northwest Beach, is that exhibited by zone D. Despite 2019 consisting of higher recorded sightings in zone C and 2020 consisting of higher recorded sightings in zone B, it was not until bold management interventions were implemented at those zones that they began to increase in abundance. The goal of the management interventions was to mimic the landscape and vegetation cover exhibited by zone D, considered to be the “model habitat” in the 2013 Northwest Beach restoration plan. Parks Canada (2013) noted that this vegetation community in this zone is Little Bluestem – Switchgrass – Beachgrass Open Graminoid Sand Dune Type. Parks Canada (2013) stated that in this location, aeolian processes dominate and, as such, large and sometimes extensive open sand patches are present. The foredune contains considerably less vascular plant diversity, and larger

areas of bare sand than the back dune. The windward fore-dune is subjected to higher rates of sand erosion/accretion and is therefore limited to a few graminoid species (Parks Canada, 2013). More detailed description of this specific habitat type and the habitat within zone D of Northwest Beach can be found in Chapter 4 Section 4.5 including composition of specific vegetation species.

5.2.3 Coastal Landform Changes Influence on Five-lined Skink Population

This section focuses on determining the coastal landform changes impact on the five-lined skink population by evaluating the variation in land use and land cover of the four zones at Northwest Beach to identify the spatial and temporal trends that lie between the landform change and the influence that change has imposed on the five-lined skink population. Observing change in the LULC classifications was an essential criterion for understanding the overall landform change, the difference in landform changes between the four varying zones, the influence that the management interventions had on landform development and how the landform change is influencing the endangered five-lined skink inhabitants. Interpreting the relationship between the overall landform change that has occurred and the influence that has had on five-lined skink abundance and distribution evaluated the success of past management interventions that were implemented between 2017 and 2020. This research objective led to the overall research goal of recommending successful rehabilitation measures for improving the Point Pelee National Parks five-lined skink population and restoring ecosystem function at Northwest Beach.



Figure 5.11: April 2017 land use land cover classification & 2017 five-lined skink abundance and distribution between NW beach research zones. Figure displays earliest land use land cover representation in this research with the corresponding 2017 skink distribution across Northwest Beach. The phrasing “site” depicted in the figure refers to the corresponding “zone” that it is referencing. The four varying “zones” are not considered individual sites in this research.

Table 5.6 shows the LULC classification class area percentages for each of the five LULC classifications. In April 2017, the composition LULC was dominated by deciduous thicket, occupying 32.8% of the classified area. The next largest class area percentage was shoreline followed by compacted sand and trails, occupying 19.5% and 16% of the study area respectively. In April 2017, the sand barren and dune (grasses) land class occupied 15.2% of the study area at Northwest Beach. Figure 5.12 shows that in zone A the deciduous thicket was located sporadically throughout the area, extending from the foredune to the forest. The sand barren and dune (grasses) land class was located sporadically between areas of deciduous thicket with small areas of sand barren and dune (red cedar treed sand dune) being located in the backdune between deciduous thicket. In 2017, there were 0 recorded sightings of five-lined skinks in zone A. In zone B large area of deciduous thicket occupied the majority of the foredune with small areas of sand barren and dune (grasses) present on the west side of the vegetated foredune. The backdune, east of the vegetated foredune was observed to be primarily compacted sand and trails class, extending from the northern extent to the southern extent of zone B, where the decommissioned and removed parking area was located. Deciduous thicket was observed adjacent to the compacted sand and trails and forest, on the eastern side of zone B. In 2017, zone B had 0 recorded five-lined skink sightings. Zone C consisted of deciduous thicket on the foredune but not as dominant and consistent as zone B. Like zone B, the backdune located in zone C primarily consisted of compacted sand and trail where the decommissioned and removed parking area was located. The area in zone C occupied by sand barren and dune (grasses) was more prominent and extended further east than the northern two zones with small areas of sand barren and dune (red cedar treed sand dune) being present. In 2017, zone C consisted of 3 recorded skink sightings. Zone D consisted of a relatively even distribution of both deciduous

thicket and sand barren and dune (grasses) throughout the foredune and backdune extending west, adjacent to the shoreline, to the site boundary located east. These two classes dominate the majority of zone D while being distributed sporadically. Small areas of sand barren and dune (red cedar treed sand dune) were present throughout the backdune of zone D. In 2017, zone D had 10 recorded five-lined skink sightings, the largest abundance of recorded sightings at Northwest Beach at that time.



Figure 5.12: May 2019 land use land cover classification & 2019 five-lined skink abundance and distribution between NW beach research zones. Figure displays the composition of land use land cover following recommendations made by Nayak (2018) and prior to management interventions implemented in fall 2019. The phrasing “site” depicted in the figure refers to the corresponding “zone” that it is referencing. The four varying “zones” are not considered individual sites in this research.

In May 2019, the composition of land use and land cover continued to be dominated by deciduous thicket, occupying 32.4% of the study area at Northwest Beach. There was no major change in occupied area of the deciduous thicket, shoreline or infrastructure and facilities classes from April 2017 to September 2019. There was a change in the area occupied by sand barren and dune (grasses) and compacted sand and trails class in the two-year period. Sand barren and dune (grasses) increased by 12.2% while compacted sand and trails decreased by 9.3% in percent area occupied. This primarily took place in zone B and zone C with most of the compacted sand and trail present in the backdune transitioning to sand barren and dune (grasses). Small areas of compacted sand and trail continued to be present in areas of the backdune of zone B. Portions of deciduous thicket on the foredune in zones B and C were thinner than the previous classification as corridors were created through the vegetated foredune in these two zones. In the southernmost section of zone C, a large area of deciduous thicket, located on the foredune in April 2017, was no longer present. There was little change in the LULC composition of zones A and D from April 2017 to September 2019. The total number of recorded five-lined skink sightings at Northwest Beach in 2019 was the largest recorded number throughout the three time periods, with 36 recorded sightings. Zone A had zero recorded five-lined skink sightings, no change from 2017. In 2019, there were 2 recorded skink sightings in zone B, an increase of 2 since 2017. Zone C had 18 total five-lined skink sightings, the largest recorded number of the four zones in 2019 and an increase of 15 since 2017. Zone D had 16 recorded five-lined skink sightings, an increase of 6 sightings from 2017.



Figure 5.13: December 2019 land use land cover classification & 2019 five-lined skink abundance and distribution between NW beach research zones. Figure displays the land use land cover composition at Northwest Beach following the management intervention implemented in fall 2019 involving the management of the artificially stabilized foredune. The phrasing “site” depicted in the figure refers to the corresponding “zone” that it is referencing. The four varying “zones” are not considered individual sites in this research.

In December 2019, the LULC composition was dominated by sand barren and dune (grasses), occupying 38.9% of the study area at Northwest Beach, an increase of 11.6% from May 2019. In December 2019, deciduous thicket occupied an area 25.9% of the study area, a decrease of 6.5% from May 2019. Additionally, the compacted sand and trail land class decreased by 1.2% from May 2019. These changes in LULC took place in zone B. In December 2019, zone B had no deciduous thicket located on the foredune and there was no prominent foredune present. Rather, the sand that had composed the foredune had been freshly dispersed throughout most of zone B including the previously decommissioned parking area. This area was classified as sand barren and dune (grasses) despite the sand being freshly dispersed. The only compacted sand and trail observed in December 2019 was a thin footpath for park visitors located adjacent to the forest, extending from the designated parking infrastructure to the decommissioned entry road north of zone B. There was a small area of compacted sand and trail in zone B, bordering the infrastructure and facilities located at the southernmost portion of the zone. The deciduous thicket present in zone A was slightly smaller in area from May 2019. There were no changes observed in the LULC composition in zones C and D in December 2019. There were no changes in recorded five-lined skink sightings in December 2019 from May 2019 as the species monitoring program was conducted on a year-by-year basis, with recordings taken place in June -July of each year.



Figure 5.14: September 2020 land use land cover classification & 2020 five-lined skink abundance and distribution between NW beach research zones. Figure displays the composition of land use and land cover in fall 2020 at Northwest Beach and the influence it imposes on the local skink population. The phrasing “site” depicted in the figure refers to the corresponding “zone” that it is referencing. The four varying “zones” are not considered individual sites in this research.

The LULC composition in September 2020 was like the composition evaluated for December 2019. In September 2020, the Northwest Beach study area continued to be dominated by the sand barren and dune (grasses) class, occupying 39.8% of the study area. A less than 1% increase from December 2019 in this land class. All other LULC classes consisted of less than 1% change from December 2019 to September 2020, with exceptions being shoreline increasing by 3.5%, and compacted sand and trail decreasing by 1.9%. This change occurred in zone B, as the area designated as freshly dispersed sand was now fully classified as sand barren and dune (grasses). Zone B primarily consisted of the sand barren and dune (grasses) class, extending from the foredune to the deciduous thicket bordering the footpath on the east side of the study site. In zone A, deciduous thicket appeared slightly thinner than in December 2019 as the sand barren and dune (grasses) class dominated areas between deciduous thicket. Zones C and D did not experience any major change in the LULC composition from December 2019 to September 2020. There were 25 total recorded five-lined skink sightings at Northwest Beach in 2019, 11 fewer than the previous year. Zone A had 5 recorded skink sightings, 5 greater than 2019. Zone B had 8 recorded skink sightings, an increase of 6 from 2019. Zone C had 5 recorded skink sightings, 13 fewer sightings than in 2019. Zone D had 7 recorded skink sightings, 9 fewer sightings than in 2019.

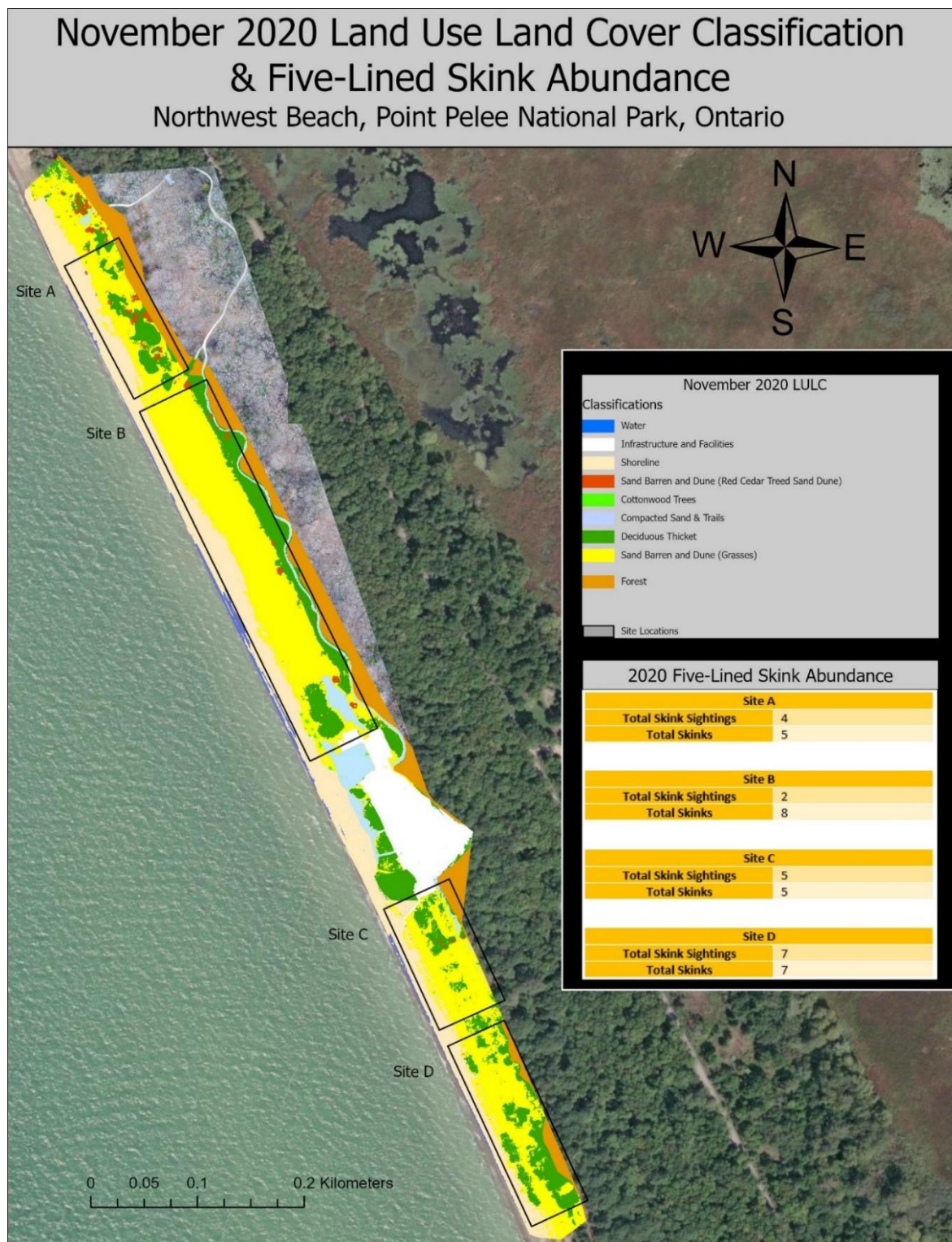


Figure 5.15: November 2020 land use land cover classification & 2020 five-lined skink abundance and distribution between NW beach research zones. Figure displays the most recent land use land cover composition and the influence it imposes on the local skink population. The phrasing “site” depicted in the figure refers to the corresponding “zone” that it is referencing. The four varying “zones” are not considered individual sites in this research.

The LULC composition for November 2020, the most recent classification date, was an almost identical composition as the LULC classification evaluated for September 2020. Sand barren and dune (grasses) decreased by 1.5%, shoreline increased by 1.2%, and compacted sand and trails increased by 1.14% in November 2020. All other LULC classes delineated in November 2020 consisted of less than 1% change from September 2020. In zone A, areas dominated by deciduous thicket appeared to be slightly larger than in September 2020. There were no other observable changes identified from the November 2020 LULC classification compared to the September 2020 classification. Zones B, C and D appeared nearly identical to the composition of these zones in September 2020 while zone A experienced a small variation in composition. There were no changes in recorded five-lined skink sighting abundance in November 2020 from September 2020 as the species monitoring program was conducted on a year-by-year basis, with recordings taking place in June -July of each year. As with the September 2020 LULC classification, zone A had 5 recorded five-lined skink sightings, zone B had 8 recorded sightings, zone C had 5 recorded sightings and zone D had 7 recorded sightings. There was a total of 25 recorded five-lined skink sightings at Northwest Beach in 2020.

Table 5.7: Land use land cover class occupied area percentage comparison between each LULC classification

LULC Class Area Percentages (%)	April 2017	May 2019	December 2019	September 2020	November 2020
Water	4.42	2.67	3.16	1.41	0.92
Infrastructure & Facilities	10.05	9.97	9.97	9.97	9.97
Shoreline	19.52	19.90	15.96	19.48	20.68
Sand Barren & Dune (Red Cedar Treed Sand Dune)	1.77	0.77	0.22	0.35	0.50
Cottonwood Trees	0.28	0.28	0.34	0.34	0.10
Compacted Sand & Trails	16.00	6.67	5.50	3.61	4.75
Deciduous Thicket	32.81	32.38	25.93	25.01	24.75
Sand Barren & Dune (Grasses)	15.15	27.36	38.92	39.82	38.33

Figure 5.17 compares the LULC classification class area percentages for April 2017, the earliest LULC classification being evaluated and November 2020, the most recent LULC classification being evaluated. Evaluating the change in LULC class area percentage that occurred over the three-year period, there was no major change in the LULC land classes of infrastructure and facilities, shoreline, and cottonwood trees from April 2017 to November 2020. Deciduous thicket, the most dominant LULC class in April 2017, decreased from occupying 32.8% of the study area, to occupying 24.8% of the study area in November 2020, an overall decrease of 8% in the three-year period. Sand barren and dune (grasses) class changed from occupying 15.2% of the study area in April 2017 to occupying 38.3% of the study area in 2020, an overall increase of 23.1%. The change resulted in this land class becoming the dominant class following the three-year period. In April 2017, compacted sand and trails land class occupied more area than sand barren and dune (grasses) at 16% of the study area. This land class decreased by 11.2% in the three-year period, occupying 4.8% of the study area in November 2020. In April 2017, sand barren and dune (Red Cedar treed sand dune) occupied 1.8% of the study area, decreasing by 1.3% in the three-year period, by November 2020 occupying 0.5% of the study area.

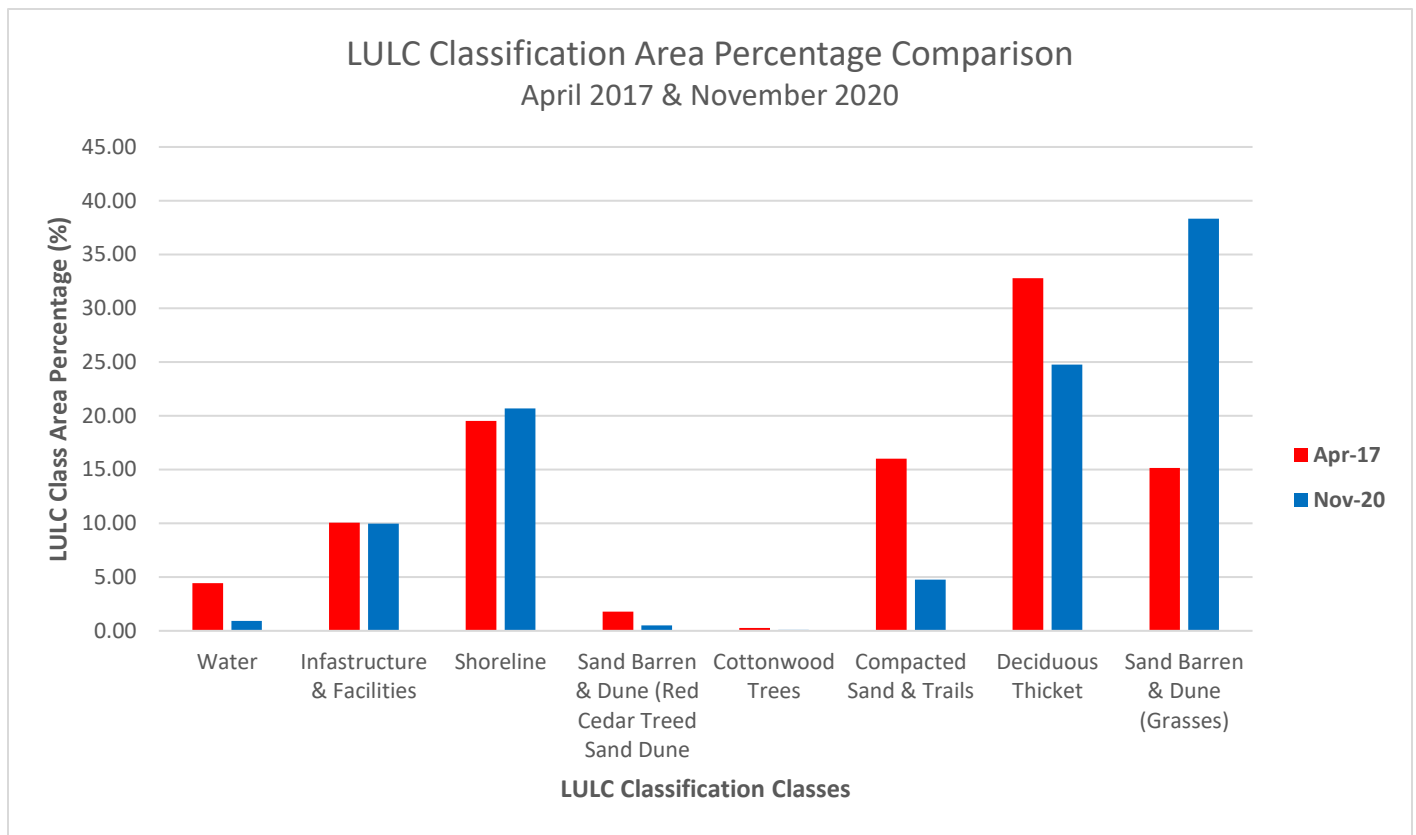


Figure 5.16: Comparison of land use land cover class area percentages of the earliest classification conducted in this research, April 2017, and the most recent classification conducted in this research, November 2020. Figure shows the overall change in land use and land cover at Northwest Beach that took place over the entire research period.

Figure 5.18 shows the comparison in five-lined skink recorded sightings at Northwest Beach, Point Pelee National Park from 2017 to 2020. In 2017, the total number of recorded five-lined skink sightings at Northwest Beach consisted of 13 sightings. By 2020, the total number of recorded five-lined skink sightings at Northwest Beach increased to 25 recorded sightings.

Within zone A of Northwest Beach, in 2017 there were 0 recorded skink sightings. In 2020, the number of recorded skink sightings in zone A increased to 5 sightings. In 2017, in zone B there were 0 recorded skink sightings. By 2020, the number of recorded skink sightings in zone B increased to 8 sightings. In 2020, zone B contained the highest recording of five-lined skink sightings throughout the Northwest Beach study area. Within zone C, in 2017 there were 3

recorded skink sightings. In 2020, the number of recorded five-lined skink sightings in zone C increased to 5 recorded sightings. In 2017, zone D consisted of 10 recorded five-lined skink sightings. By 2020 the number of recorded skink sightings in zone D decreased to 7 sightings. Zone D was the only zone that experienced a decrease in recorded five-lined skink sightings from 2017 to 2020.

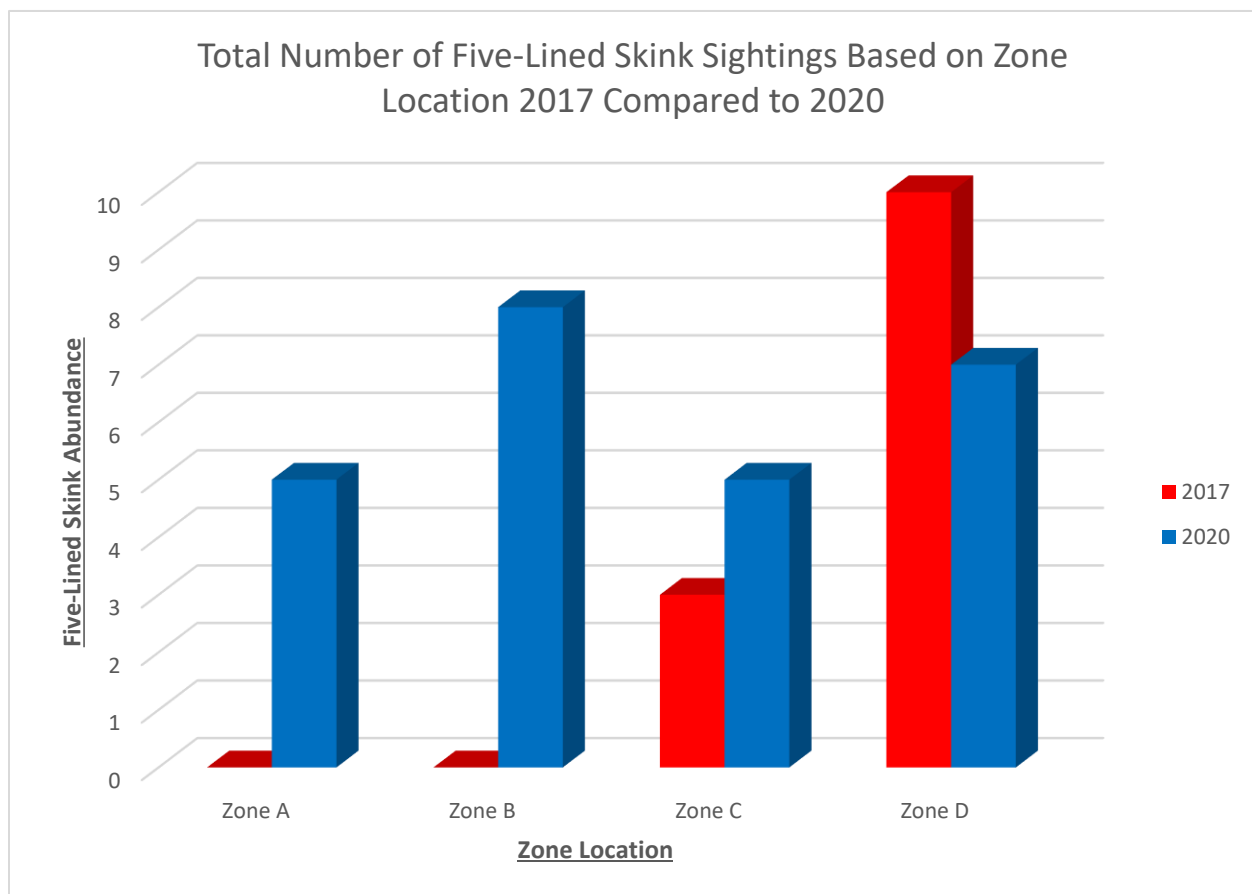


Figure 5.17: Figure details the comparison of total five-lined skink recorded sightings between 2017 and 2020 across each Northwest Beach research zone. Figure displays the change in species distribution and overall abundance that occurred over the entire research period.

5.2.3.1 Discussion

As previously mentioned, this section focuses on addressing objective three of the research, determining the coastal landform changes influence on the endangered five-lined skink population, specifically at Northwest Beach, Point Pelee National Park. Section 5.2.2 determined that the preferred habitat composition of the five-lined skink, based on the four varying zones at Northwest Beach, is that exhibited by zone D. In 2017, the five-lined skink population primarily resided in zone D, with 10 of the 13 total recorded sightings being from this zone. At this time, the species distribution across Northwest Beach was very limited with there being 0 recorded sightings in zone A, 0 recorded sightings in zone B and the remaining 3 sightings being recorded in zone C. Exhibited in the April 2017 LULC classification, zones B and C were the focus of management interventions involving the removal of parking lot infrastructure and removal of gravel materials that previously based the parking area. The land cover that was present at the time and the habitat composition throughout zone B and zone C created a fragmented landscape that limited the five-lined skink from distributing further north at Northwest Beach. Zone D, the model habitat, consists of a Lake Erie Sandspit Savannah habitat with ecosystem function capable of sustaining the five-lined skink population. This resulted in most of the population residing in zone D of the study area at that time. In April 2017 the LULC classification determined that Northwest Beach was dominated by deciduous thicket, followed by shoreline, and compacted sand and trails. Based on observations made regarding the areas dominated by these land cover classes, the composition of land cover at that time limited the five-lined skink from increasing population distribution at Northwest Beach. The LULC composition was fragmenting the landscape and creating unfavourable habitat conditions for the local skink

population. In April 2017, only 15.2% of the Northwest Beach study area consisted of the sand barren and dune (grasses) land use class.

Observations made from the May 2019 LULC classification indicated that the Northwest Beach study area experienced land cover change primarily in the sand barren and dune (grasses) class as it increased in areas dominated by compacted sand and trails in April 2017. Most of this change took place in zone C with increases in sand barren and dune (grasses) observed additionally in the backdune of zone B. Following management interventions that were based on recommendations made by Nayak (2018), that were implemented in zone C, the overall abundance of five-lined skinks increased to a total of 36 recorded sightings at Northwest Beach. The number of recorded five-lined skink sightings in zone C increased from 3 in 2017 to 18 in 2019. In 2019, the highest number of recorded sightings across Northwest Beach were counted in zone C. In zone D there were 2 fewer sightings, accounting for 16 sightings in total. In 2019 the increase in recorded skink sightings in zone C directly coincided with an increase in sand barren and dune (grasses) and a decrease in compacted sand and trail in zone C. Zone B additionally experienced an increase in recorded skink sightings, accounting for 2 total sightings in 2019. The increase in sightings of zone B also coincided with a slight increase in sand barren and dune (grasses) class that took place in the backdune of zone B, observed in the May 2019 classification. The landscape became less fragmented and began shifting towards favourable habitat conditions of the local skink species following the management interventions implemented in zone C. The change in LULC and increase in five-lined skink abundance indicated the improvement of ecosystem function in zone C of Northwest Beach. The May 2019 LULC classification indicated that the sand barren and dune (grasses) class increased to 27.4%

of the Northwest Beach study area with deciduous thicket continuing to be the dominant land class at that time.

As previously mentioned, the five-lined skink monitoring program was conducted on an annual basis during June / July of each year, resulting in the December 2019 classification being associated with the same population distribution and overall abundance as May 2019. By December 2019, the management interventions that were implemented in zone B changed the LULC composition greatly. These interventions involved the heavily vegetated foredune that was present in zone B being pushed over, with the corresponding sand supply being dispersed throughout the zone B area. This intervention led to land cover changes throughout zone B. Invasive species had been removed from the area entirely while previously potted native vegetation species were replanted throughout the zone. The December 2019 LULC classification shows that major changes primarily took place in zone B and that the changes in LULC were a result of the management interventions implemented in fall 2019. In zone B, indicated as freshly dispersed sand, there was a large increase in the area occupied by sand barren and dune (grasses) land class and decrease in area occupied by deciduous thicket and compacted sand and trail. The management intervention included the reintroduction of woody debris from nearby debris piles being distributed throughout zone B and the continued removal of invasive species through mechanical means.

Following the management interventions implemented in fall 2019, the changes in land use and land cover of zone B were maintained in the following September 2020 and November 2020 classifications. The change was primarily in the sand barren and dune (grasses) and

deciduous thicket land classes for both 2020 classifications. The sand barren and dune (grasses) class increased to 39.8% of the Northwest Beach study site in September 2020 and 38.3% of the study site in November 2020. The deciduous thicket land class decreased to 25% of the study site in September 2020 and 24.8% of the study site in November 2020. The changes coincided with a slight decrease in the overall abundance of five-lined skink sightings recorded at Northwest Beach, decreasing from 36 sightings in 2019 to 25 sightings in 2020. Despite the decrease in abundance, the second highest recorded number of skink sightings throughout Northwest Beach occurred in 2020. The management interventions that were implemented in fall 2019 involved intensive rehabilitation practices that would have contributed to the decrease in recorded sightings. The management interventions involved scaring away any skinks present in the rehabilitation area prior to the implementation of rehabilitation practices. The management practices themselves, once initiated, would have additionally scared away individual skinks from the area as heavy machinery was involved in the process. The initial removal of native species and woody debris along with dispersing fresh sand throughout zone B would have temporarily influenced the species and contributed to the slight decrease in recorded sightings in 2020.

Despite the slight decrease in recorded five-lined skink sightings at Northwest Beach from 2019 to 2020, the population distribution increased greatly in 2020. In 2020, the number of recorded skink sightings had increased to 5 in zone A and increased to 8 in zone B. Zone C decreased to 5 total sightings while zone D decreased to 7 in total. The increase in recorded skink sightings in zone A and B with the corresponding decrease in zone C and D indicates a reduced fragmentation of the Northwest Beach landscape. This allowed for the residing skink population to distribute further north, up the northwest coast of Point Pelee National Park. The increased

population distribution recorded in 2020 directly coincides with the increase in sand barren and dune (grasses), and the reduction in deciduous thicket that primarily occupied the artificially stabilized foredune of zone B. This indicates that the management interventions implemented in fall 2019, as well as the rehabilitation practices recommended by Nayak (2018) were successful in improving ecosystem function at Northwest Beach. It should be noted that the management interventions included the designation of rehabilitation areas through the installation of informative signs, deterring park visitors from accessing the active rehabilitation zones. This reduced park visitor traffic to these areas of Northwest Beach, which would have additionally influenced the increase in five-lined skink distribution and overall abundance.

CHAPTER 6

Conclusions & Recommendations

6.1 Introduction

This chapter presents the conclusions based on the objectives of this research, followed by recommendations for future rehabilitation practices at Northwest Beach.

6.2 Key Conclusions of the Research

There was significant change in land use and land cover at Northwest Beach as a result of management interventions. The LULC classification found that in April 2017, the Northwest Beach landscape was dominated by deciduous thicket and compacted sand & trails classes. The deciduous thicket was primarily associated with the vegetation that dominated the artificially stabilized foredune in zone B as well the remaining deciduous thicket that was located sporadically throughout the remaining three zones. In April 2017, the areas consisting of the compacted sand & trails land class was largely associated with the active management interventions occurring at the time. This included the sediment that based the decommissioned parking lot areas in zone B and zone C. The heavily vegetated foredune that was dominated by deciduous thicket was restricting the transport of sediment into the backdune of the decommissioned parking lot areas. In April 2017, the deciduous thicket land class occupied 32.8% of the Northwest Beach study site. The May 2019 LULC classification indicated that there was an increase in area occupied by the sand barren and dune (grasses) land class and a decrease in compacted sand and trail. The change primarily took place in zone C, indicating the

success of the rehabilitation practices recommended by Nayak (2018). Despite the deciduous thicket land class continuing to be the most dominant in May 2019, breaks created through the foredune promoted the transport of a limited supply of sand to the backdune, into the decommissioned parking areas. The removal of invasive vegetation species, particularly from the breaks, as well as reduced park visitor traffic into the active rehabilitation zones additionally supported the transport of sand into the decommissioned areas.

The management interventions implemented in fall 2019 were a dominant factor in changing the land use and land cover of the Northwest Beach study site landscape. The December 2019 LULC classification indicated a large decrease in the area occupied by deciduous thicket along with a large increase in the area occupied by sand barren and dune (grasses). Following the fall 2019 management interventions, deciduous thicket decreased by 6.5% in percentage of occupied area while sand barren and dune (grasses) became the dominant land class, increasing by 11.6%. The change in land cover mainly took place in zone B as this was the area in which the management interventions were focussed. The September 2020 and November 2020 LULC classifications indicated the continued success of the management interventions from fall 2019 and that the positive results of the practices were maintained. The November 2020 LULC classification indicated that sand barren and dune (grasses) continued to be the dominant land class, occupying 38.3% of the Northwest Beach study site. Observations made in November 2020 indicated that dune associated vegetation species, particularly native marram grass, had increased in density throughout the foredune of zone B. This further validated the success of the management interventions implemented in fall 2019 and the active rehabilitation practices being conducted throughout the site. Northwest Beach has experienced a

shift towards a sand barren and dune (grasses) dominated landscape that has facilitated the formation of natural dune landforms.

The trends in five-lined skink sighting for the Northwest Beach population were compared to the trends in population abundance of the entire Point Pelee National Park population. Since 2014, when management interventions involving decommissioning and removal of infrastructure at Northwest Beach began, the Northwest Beach population has followed similar trends in abundance exhibited by the entire PPNP population. Between 2014 and 2017 both the Northwest Beach population and the entire PPNP population experienced declines in abundance with 2017 being the lowest recorded abundance in the seven-year period. Following 2017, the PPNP skink population as well as the Northwest Beach population experienced increases in abundance up until 2020. In 2020 the PPNP skink population abundance continued to increase. In 2020, the Northwest Beach population experienced a slight decline in abundance. The decrease in sightings at Northwest Beach is associated with the management interventions implemented in fall 2019 that involved scaring away individual skinks from the working rehabilitation areas prior to and during active management practices. Despite the slight decline, 2020 was the second largest abundance recorded at Northwest Beach.

Prior to the management interventions implemented in fall 2019, the Northwest Beach five-lined skink population was primarily located in zone D. The rehabilitation practices recommended by Nayak (2018) that were conducted between 2018 and 2019, promoted the local skink population to expand further into zone C. Although these practices did not influence the species to expand further north toward the other two zones. This was validated by the 2019 five-

lined skink distribution at Northwest Beach, indicated by the increased skink abundance in zone C. The increased abundance in 2019 resulted in both zone C and zone D becoming the dominant areas inhabited by the Northwest Beach five-lined skink population. The recommended rehabilitation practices were performed based on zone D being the model habitat to mimic for habitat composition. Parks Canada (2013) described the model habitat to be classified as Little Bluestem – Switchgrass – Beachgrass Open Graminoid Sand Dune Type and that this model habitat will guide the overall goal of the restoration project at Northwest Beach. This includes examples of desired foredune and backdune habitats with representative herbaceous and woody vegetation, and desired dune formations (Parks Canada, 2013). Parks Canada (2013) stated that once sand movement begins in the restoration areas, a gradual transition of habitats, from beach, to marram grass to patchy shrubs to backdune habitat will be created. Parks Canada (2013) noted that this habitat is dominated by aeolian processes and as such, large and sometimes extensive open sand patches are present. The foredune contains considerably less vascular plant diversity and larger areas of bare sand than the backdune (Parks Canada, 2013). Parks Canada (2013) noted that the windward foredune is subjected to higher rates of sand erosion/accretion and is therefore limited to a few graminoid species.

The April 2017 LULC classification determined that Northwest Beach was dominated by the deciduous thicket land class with compacted sand and trail dominating the decommissioned parking areas of zone B and C. The composition of land use and land cover at that time was limiting the five-lined skink from increasing its population distribution north of zone D, creating a fragmented landscape with unfavorable habitat conditions for the species. Following the rehabilitation recommendations made by Nayak (2018), in 2019 the skink abundance in zone C

had increased along with the Northwest Beach population increasing to its highest recorded abundance. The increase in five-lined skink abundance directly coincided with an increase in sand barren and dune (grasses), indicating a shift toward a less fragmented landscape and more favorable habitat conditions. Following the management interventions in fall 2019, sand barren and dune (grasses) became the dominant land use class at Northwest Beach along with a reduction in area occupied by deciduous thicket and compacted sand and trail. The shift in the composition of land use and land cover was validated by the December 2019, September 2020, and November 2020 LULC classifications, indicating the shift toward a sand barren and dune (grasses) dominated landscape. As a result of the management interventions, by 2020 the five-lined skink population distribution at Northwest Beach had increased greatly. Both zone A and zone B experienced increases in skink abundance while zone C and zone D maintained a presence of the species. The expansion of the species into the northern two zones and the species ultimately inhabiting all four zones across Northwest Beach in 2020 alludes to the success of the fall 2019 management activities. Northwest Beach shifted toward a sand barren and dune (grasses) dominated landscape that was less fragmented. The continued rehabilitation practices conducted at Northwest Beach, primarily involving invasive species management, has promoted the natural succession of the coastal dune ecosystem and natural development of the dune landform. The past management practices at Northwest Beach have led to an improvement in overall ecosystem function that has resulted in increased five-lined skink abundance and distribution.

To conclude, the rehabilitation practices implemented at Northwest Beach, and specifically the management interventions that took place in fall 2019 have been successful in

consistently shifting the land cover composition to that exhibited by zone D, the model habitat. The management practices have promoted the natural succession of the coastal dune ecosystem and development of the coastal dune landforms at Northwest Beach. The increase in endangered five-lined skink population abundance and distribution emphasizes the influence that landform change has on the local population and validates the success of past management interventions in continuing to restore ecosystem function at Northwest Beach. The restoration of the coastal dune habitat, specifically at Northwest Beach, remains a complex process and the development of restoration practices and management approaches for the improvement of the coastal dune habitat should remain a priority for Parks Canada.

6.3 Recommendations for Future Rehabilitation

The results of this research will help to inform future management interventions and rehabilitation practices implemented at Northwest Beach, Point Pelee National Park, and aid in the progression of management plans that are adaptive in nature. USACE (2021) stated that beaches and dunes are inherently dynamic systems that reduce land loss and inundation risk of the hinterland while providing high amenity and environmental benefits. The design of beach and dune natural and nature-based features should include management requirements, strategies, and associated monitoring needs (USACE, 2021). USACE (2021) stated that it should be planned to let nature do most of the work when managing or implementing a beach and dune system as a natural and nature-based feature for coastal resilience. For beach and dune systems, the design should align with the original beach and dune as much as possible. Mimic or re-create as far as possible the natural conditions of the location in question to let nature do most of the

work and reduce maintenance requirements (USACE, 2021). Further, sediment should be placed where winds, waves, and tides can assist in transport for beach and dune building. USACE (2021) noted that ecologically sustainable beach and dune systems require healthy habitat conditions and supporting processes to be in place. Once these conditions exist, colonization by appropriate flora and fauna is likely (USACE, 2021). The natural regeneration of vegetation will be encouraged and augmented as needed with appropriate native pioneer species seeding and planting (USACE, 2021). The following recommendations regarding future habitat monitoring and rehabilitation practices at Northwest Beach are based on past management strategies exercised by Parks Canada at Point Pelee National Park. The following recommendations are separated based on whether it is specific to the Point Pelee landscape or if it can be further applied to additional coastal rehabilitation projects outside of the Point Pelee location.

Recommendations specific to Point Pelee National Park:

1. The model habitat, zone D, should continue to be used to guide the rehabilitation process, the development of management practices and the overall goal of the restoration projects implemented at Northwest Beach.
2. The continued monitoring of land use land cover at Northwest Beach is necessary for improvement of the overall management approach going forward. This includes the continued collection of aerial imagery to support a database with consistent imagery dates to monitor land cover change over time. Expansion of deciduous thicket into the rehabilitation areas should be monitored as it acts as a barrier restricting the transport of

sediment into the backdune areas. Monitoring of sand accretion and overall sediment transport should be associated with future LULC analysis.

3. If deemed necessary, continued addition of woody debris into rehabilitation areas at Northwest Beach for five-lined skink habitat enhancement.
4. Continue to conduct vegetation monitoring to determine the success of seeded and transplanted flora, the progression of the dune associated vegetation and the corresponding successional species as well as any introduction of invasive species to Northwest Beach. This recommendation can be further applied to areas outside of Point Pelee if similar vegetation management was applied to the rehabilitation process.

Recommendations for future coastal dune rehabilitation that can be further applied to areas outside of Point Pelee National Park:

5. Prevention of park visitor access to active rehabilitation areas should continue. Visitor access to these areas could be detrimental to the success of early successional dune species such as native marram grass. These dune species help trap sediment for dune development and taking steps to minimize trampling is considered an important aspect of the restoration process. Interpretive signs should be maintained along dune and rehabilitation areas, preventing visitor access to rehabilitation areas, and directing traffic toward designated paths located outside of active rehabilitation areas.
6. Conservation and protection of native dune species such as marram grass, a dominant dune associated species, is highly recommended to further enhance the process of dune restoration.

7. Beach cleaning processes such as intensive beach raking should be halted as it has been at Northwest Beach, Point Pelee National Park, as these activities destroy vegetation cover and restrict natural regeneration of species such as dune grasses.
8. If necessary, the plantation of native dune associated species to increase density to further promote sand accretion in the rehabilitation areas.
9. Continued removal of invasive species such as meadow vegetation through mechanical means (hand pulling) to prevent early succession of the forest ecosystem. Rehabilitation areas should continue to be monitored for invasive species to be removed from the active rehabilitation area entirely if detected.

Appendix



May 2019 Raw Imagery

Northwest Beach, Point Pelee National Park, Ontario



December 2019 Raw Imagery

Northwest Beach, Point Pelee National Park, Ontario



September 2020 Raw Imagery

Northwest Beach, Point Pelee National Park, Ontario

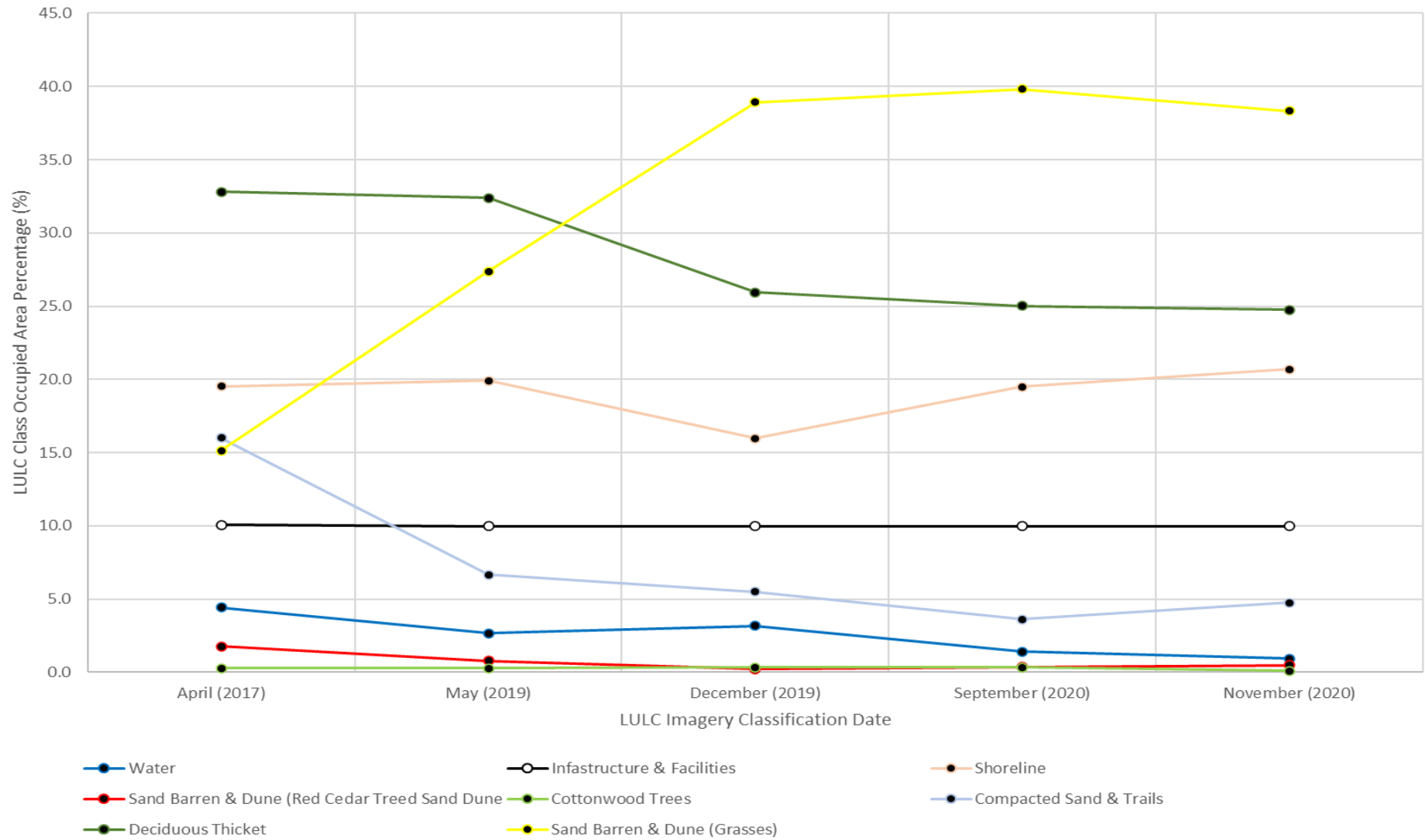


November 2020 Raw Imagery

Northwest Beach, Point Pelee National Park, Ontario



PPNP LULC Class Area Percentage (%) Comparison Between Each Classification
April 2017 - November 2020



LULC Class Area In sq. m (m²)	April 2017	May 2019	December 2019	September 2020	November 2020
Water	3232.78	1953.88	2307.41	1030.54	674.64
Infrastructure & Facilities	7346.06	7288.06	7288.06	7288.06	7288.06
Shoreline	14264.28	14540.64	11662.78	14235.56	15108.75
Sand Barren & Dune (Red Cedar Treed Sand Dune)	1296.44	563.52	163.86	258.69	362.20
Cottonwood Trees	201.29	201.28	246.01	246.00	71.34
Compacted Sand & Trails	11690.13	4871.91	4015.56	2641.13	3470.64
Deciduous Thicket	23972.29	23659.66	18948.37	18274.82	18082.41
Sand Barren & Dune (Grasses)	11066.68	19991.70	28438.11	29095.35	28010.30
Total Area	<i>73069.95</i>	<i>73070.65</i>	<i>73070.16</i>	<i>73070.16</i>	<i>73068.34</i>

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