What species comprise the community of potential predators of the Piping Plover at St. Catherine River Beach?

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Abstract

The Piping Plover (*Charadrius melodus*) is known to breed on St. Catherines River Beach at Kejimkujik Seaside every year. This beach is closed to the public during the breeding season from mid-April or May to mid-August in order to avoid human disturbance that may interfere with fledging success. The area is closely monitored by park employees in order to determine reproductive success and predation on Piping Plover eggs and chicks. Despite this predation occurs every year and poses a significant threat to the reproductive success of the plovers. In order to implement predation management techniques to be employed the predator community needs to be addressed. St. Catherines River Beach was monitored from 25 June to 14 November 2009 to assess the make-up of the potential predator community. The potential predators identified consisted of 4 avian and 7 mammalian predators. The most prominent potential avian predators were the Herring Gull, the Great Black-backed Gull, and the American Crow. The most prominent potential mammalian predator was found to be the red fox. This study recommends that management techniques that reduce predation of gulls (*Larus* spp.), crows (*Corvus brachyrhynchos*), and depredating mammalian species should be the main focus to increase reproductive success of plover at St. Catherines River Beach.

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1.0 Introduction

The Piping Plover (*Charadrius melodus*) is a migratory shorebird which breeds on Atlantic coastal beaches in Canada and the United States (Haig and Oring 1985). The wintering grounds of the plover are along the southern Atlantic coast of the United States from North Carolina to Florida (Haig and Oring 1985; Haig 1992). The Piping Plover consists of two subspecies, *Charadrius circumcinctus and Charadrius melodus* of which the former breeds in areas of the Northern Great Plains and Great Lakes (Goossen et al. 2002). The wintering grounds of the inland populations are found along the coast of the Gulf of Mexico from Florida to Mexico (Environment Canada 2006).

The plover has faced serious population declines since 1945 and has been recognized as an endangered species since 1985 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Haig 1985; Haig 1992). It was during 1985, that Kejimkujik National Park and Historic Site acquired 22.2 km² of land on the South Shore of Nova Scotia (Corbett 1997). The area now called Kejimkujik Seaside contains two beach and sand dune systems: Port Joli Beach and St. Catherines River Beach (St. Catherines). Nesting activity and behaviour of the Piping Plover has been the focus of many studies on St. Catherines River Beach. A study conducted by Cairns (1977) noted the fledging success of Piping Plovers at St. Catherines, which was between 27 and 29 pairs. According to Park documents, that number has decreased between 4 and 10 pairs (Parks Canada 2009). Human disturbances, predation during the breeding season, and habitat loss or alteration have been suggested as factors contributing to population decline (Flemming et al. 1988; Haig and Oring 1988; United States Fish and Wildlife Service 1994; Boyne 2001). This decline has been addressed by numerous conservation efforts such as public education to limit human disturbance, habitat management, and conservation zones (Flemming

and Gautreau 1994; Goossen et al. 2002).

Predator management is one method used to increase productivity and is practised on certain nesting beaches in Atlantic Canada. Predator exclosures are used to protect the nest from avian and mammalian predators (Environment Canada 2006). These exclosures have proven to increase hatching success and overall productivity (Corbett 1993). Predator exclosures have been used at St. Catherines River Beach and have had mixed results. Fledging success has varied year to year and in 1991, 7 exclosed nests were lost to predators and 2 were abandoned by adult plovers (Parks Canada 2009; Austin-Smith et al. 1991). During 1991 and 2000, an average of 10 chicks fledged each year from exclosed nests (Parks Canada 2009). These results indicate that nest exclosures overall increase the fledging success of plovers and are effective against depredating animals.

1.1 Research problem

In order to facilitate the recovery of the Piping Plover at St. Catherines River Beach, conservation management has focused on reducing human disturbance at nesting beaches and enhancing nesting habitat (Goossen et al. 2002). However, predator control techniques have been overlooked in recent years. Predation remains to be one of the greatest threats to Piping Plover eggs and chicks and is anticipated to continue to be a serious threat (Environment Canada 2006).

Due to the continued decline of the Piping Plover at Atlantic Canada sites, management that minimizes the impact of predation is needed. The protection of nests using wire predator exclosures eliminates predation on eggs. However, no protection is given to the hatched chicks, making them vulnerable to predation. In order for management to be successful at Kejimkujik Seaside, predation management should focus on techniques that will eliminate or lessen

predation during both the egg and chick phase.

Predators of the Piping Plover have been recorded at various breeding locations, but the predators that reside at St. Catherines are relatively unknown. This project will investigate what species comprise the community of potential predators of the Piping Plover at St. Catherines River Beach. A full review of literature will be conducted to provide vital information on effective management to be considered at Kejimkujik Seaside. Additionally, this project will provide further knowledge about predation, such as spatial, seasonal, and lunar variations.

1.2 Motivation for study

Kejimkujik Seaside provides nesting habitat to the Piping Plover every year. There are only three nesting sites in National Parks where plover nests, Kejimkujik National Park, Kouchibouguac National Park in New Brunswick, and Prince Edward Island National Park (Corbett 1997). These national parks are essential for providing Piping Plovers with protected habitat in which human disturbance is limited. Conservation of the Piping Plover is crucial because humans have played a major role in their population decline. Along the Atlantic coast, human disturbance through beach visitation stands out as a major factor decreasing Piping Plover nest success (Goossen et al. 2002). Although recovery efforts focusing on education to increase awareness about the plover have been employed, the increased presence of humans still places pressure on the shorebird's reproductive success. In instances where human presence is prevalent or areas when there is ineffective litter management, predation can increase causing an added pressure to the shorebirds (Goossen et al. 2002).

At Kejimkujik Seaside, nesting habitat on St. Catherines River Beach is closed off to the public. This has aided Piping Plover productivity and increased fledging success (Parks Canada 2009). The park also has several employees that observe the nesting plovers throughout the

breeding season. In 2009, 6 plovers were breeding on St. Catherines and 2 nests were successful, while 2 were unsuccessful (D. Smith, personal communication. March 29th, 2010). It was determined that 1 nest was lost to unknown causes and 1 was predated by gulls (D. Smith, personal communication, March 29th, 2010). In order to better understand the loss of these nests, the community of potential predators needs to be address in order for effective management to be employed that will further increase the fledging success at St. Catherines River Beach.

2.0 Literature review

The review was conducted using the following databases: Web of Science, JSTOR, Science Direct and ProQuest. Search terms "piping plover," "predation," and "predator of piping plovers" were used. Additional information was obtained through Environment Canada, Parks Canada, and Canadian Wildlife Service.

The principal objective of this literature review is to summarize knowledge pertaining to effective conservation management techniques that will lead to an increase in Piping Plover reproductive success. This review will examine what is known about potential predators of the Piping Plover and about predator control techniques that can be used to reduce predation on eggs and chicks.

2.1 Potential predators of the Piping Plover

In recent decades the population of Piping Plovers has drastically declined due to human disturbance, habitat loss, nest flooding, and predation (Flemming et al. 1988; Haig and Oring 1988; Boyne 2001). Patterson et al. (1992) and Haig (1992) both suggest that predation on eggs and chicks are highly important factors that contribute to low Piping Plover productivity. In the Northern Great Plains, depredation of Piping Plover nests and chicks was found to be the main limiting factor in productivity (Whyte 1985; Haig and Oring 1988; Richardson 1999). Research

conducted on Assateague Island, Virginia, showed that nest predation was the major factor contributing to low productivity (Patterson et al. 1991). The latter study found that chick morality was influenced by predation rates, as well as quality of the foraging areas and human disturbance (Patterson et al. 1991). Reproductive losses tend to occur equally during the egg and chick phases (Murphy et al. 2000). Therefore, it is important to determine the sources of predation at both phases, in order to assess proper management techniques.

Human disturbance on Piping Plover habitat continues to have direct and indirect effects on productivity. One indirect effect is the increased predatory pressure attributed to an increase in human refuge left behind by beach-goers (Burger 1994; USFWS 1994; Lauro and Tanacredi 2002). Predators known to be attracted to instances of litter on beaches are gulls, raccoons, foxes and skunks (USFWS 1996; Goossen et al. 2002; Lauro and Tanacredi 2002). A study conducted in Cape Cod, Massachusetts, determined that beaches with more intensive human use had higher predation rates on plovers and higher fox track density (Strauss 1990). As the amount of human activities increases, so does the populations of predators, thereby enhancing predation on the Piping Plover.

Predation on Piping Plovers is an event rarely witnessed and thus identification of predator species can be problematic (Environment Canada 2006). Predator identification has largely been gathered from tracks, nest condition, or other sources of evidence (Environment Canada 2006). In order to determine what predators could potentially pose a threat to the piping plover at St. Catherines River Beach, it is best to know what species have preyed on piping plover eggs and chicks elsewhere. Throughout the years, known or suspected predators of Piping Plover eggs and/or chicks have included: coyotes (*Canis latrans*) (Harris 1993), raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*) (Ivan and Murphy 2005), red foxes (*Vulpes*

vulpes) (MacIvor et al. 1990; Loegering and Fraser 1995), mink (*Mustela vison*) (Haig 1992; Mabee and Estelle 2000; Ivan and Murphy 2005), dogs (*Canis familiaris*) (Kruse et al. 2002), ground squirrels (*Spermophilus* spp.) (Smith and Heilhecker 1995; Mabee and Estelle 2000; Ivan and Murphy 2005), American badger (*Taxidea taxus*), long- tailed weasel (*Mustela frenata*) (Mayer and Ryan 1991), Peregrine Falcon (*Falco peregrinus*) (Hyde 1999; Goossen et al. 2002), Short- eared Owls (*Asio flammeus*) (Goossen et al. 2002), Great Horned Owls (*Bubo virginianus*) (Kruse et al. 2002), Black- billed Magpies (*Pica hudsonia*) (Licht and Johnson 1992), American Kestrels (*Falco sparverius*) (Kruse et al. 2002), Northern Harriers (*Circus cyaneus*) (Ivan and Murphy 2005), American Crows (*Corvus brachyrhynchos*) (MacIvor et al. 1990; Kruse et al. 2002; Lauro and Tanacredi 2002), Common Ravens (*Corvus corax*) (Schmelzeisen et al. 2004), and gulls (*Larus* spp.) (Whyte 1985; Patterson et al. 1991; Lauro and Tanacredi 2002). Not all of the predators listed above all have been recorded at St. Catherines River Beach or at other Atlantic Canada nesting sites.

Mabee and Estelle (2000) suggest the first step of predator management is to identify which predators are responsible for nest failure. Predation that occurs during the egg phase can be readily identified due to the known location of nests or the help of nest cameras, while predation of the chicks is rarely observed and the remains of chicks are rarely found (Environment Canada 2006; Parks Canada 2009). Losses of plover eggs or chicks tend to be site-specific (Kruse et al. 2002) and predation of plover eggs and chicks includes both avian and mammalian predators. For example, Ivan and Murphy (2005) reported that chick predation on alkali lakes in Montana and North Dakota were from avian predators. Other studies conducted show that large gulls and mammalian carnivores were the most important nest predators in parts of North Dakota (Mayer and Ryan 1991). Other studies suggest that both eggs and chicks are

very susceptible to mammals (Wiens and Cuthbert 1984; Whyte 1985; Haig and Oring 1988). Therefore, in order for predation management to be effective, techniques that protect the Piping Plover chicks and eggs from all potential predators should be reviewed.

2.2 Predator control techniques

The decline of the Piping Plover can be lessened by using management techniques such as predator barriers and predator reduction in order to improve reproductive success (Larson et al. 2002). In many situations, predator exclosures provide the most effective protection against avian and mammalian predators (Melvin et al. 1992); on the other hand electric fences are the most effective protection against large mammalian predators (Larson et al. 2002). Other techniques, such as reduction and removal of predators have had mixed success (USFWS 1996). This review will consider management strategies designed to benefit Piping Plover eggs and chicks.

2.3 Predator exclosures

Predator exclosures are constructed directly around plover nests to ensure protection from avian and mammalian predators (Schmelzeisen et al. 2004). Predators such as gulls, crows, red foxes, striped skunks, and raccoons were effectively deterred using predator exclosures (Rimmer and Deblinger 1990; Strauss 1990; Melvin et al. 1992). Rimmer and Deblinger (1990) found nests with exclosures had significantly higher hatching success (3.5 chicks/nest) than nests without exclosures (1.0 chicks/nest). Another study showed an increased nest success from 45% to 84% with the use of predator exclosures (Murphy et al. 2003b). Predator exclosures have proved successful in protecting the nest during the hatching stages (Corbett 1993; Rimmer and Deblinger 1990; Smith and Heilhecker 1995; Heckbert and Cantelon 1996). However, adult plover mortality has occurred at cages applied in the northern Great Plains (Murphy et al.

2003a). It is important to realize that when an adult plover is killed this will almost always result in the death of eggs or chicks of that plover (Murphy et al. 2003a). In order to better understand the effectiveness of predator exclosures, it is best address the species community in order to determine if there is a threat to adult Piping Plovers nesting in enclosed cages.

Predator exclosures consist of wire cages which usually have a wire or bird netting cover (Murphy et al. 2003a; Ivan and Murphy 2005). The materials used and exact design varies depending on location, but standard recommendations include 5.0 cm x 5.0 cm holes or 10.0 x 5.0 cm holes to allow adult plovers to readily enter and exit (Schmelzeisen et al. 2004). The cover either consists of a bird netting or wire top (Ivan and Murphy 2005); however, in some instances these covers were replaced with fruit-tree netting or a wire with a ring of spikes to discourage perching by avian predators (Murphy et al. 2003a). Cages are often secured to the ground using iron stakes or pegs hooked to the wire mesh to provide additional support to the exclosure (Murphy et al. 2003a; Schmelzeisen et al. 2004). Predator exclosures vary in size an can be large or small and are generally circular, triangular, or square galvanized wire fencing. Predator exclosures using larger, triangular wire have been proven to be successful in protecting nests (Rimmer and Deblinger 1990). Exclosures with smaller diameters have been used in Alberta and have showed to be effective and are thought to be less conspicuous than larger exclosures (Schmelzeisen et al. 2004). However, adult plovers have been killed by predators at smaller cages (1.0 - 1.7 m diameter) (Murphy et al. 2003a). Additionally, larger cages (3- 4 m in diameter) reduced the proportion of adult plovers killed from 34% to 11% (Murphy et al. 2003a). A study conducted by Vaske et al. (1994) showed that abandonment occurred at 10% of nests protected by exclosures. It was determined that weather conditions and use of self-supported, smaller predator exclosures played a part in the birds' behaviour patterns which increased

abandonment in this particular case (Vaske et al. 1994). Vaske et al. (1994) determined that nest exclosures may draw the attention of predators that can readily sense adult plovers, thereby causing alarm and subsequent nest abandonment. However, exclosures that were closely monitored and used larger exclosures were overall effective in increasing nest and hatching success (Vaske et al. 1994). Although exclosures prove to increase productivity and reduce predation in most locations, precautious should be taken when erecting the exclosures in order to limit adult plover predation and nest abandonment.

2.4 Electric fences

Large mammalian predators, such as coyotes and red foxes, are best deterred from eggs and chicks with electric fences placed between a nesting beach and surrounding upland (Mayer and Ryan 1991; Larson et al. 2002). In South Dakota, the mean nest survival at beaches with electric fencing was 71% greater and the mean chick survival was 55% greater than at unfenced beaches (Mayer and Ryan 1991). Nest success increased by 106% when mammalian predators were prevented from accessing nesting areas using electric fencing in North Dakota and Montana (Ivan and Murphy 2005). Both studies constructed 1.1-1.3 m high fences reinforced with T-posts along the beach area (Mayer and Ryan 1991; Ivan and Murphy 2005). Mayer and Ryan (1991) used 2.5 cm wire mesh size fencing, while Ivan and Murphy (2005) used 5 x 10 cm mesh size and 9 x 30 cm mesh size for permanent and electric fencing, respectively. When both types of fencing were employed in North Dakota and Montana, non-electrified extensions (5-15 m) were placed at each end to discourage predators from wading through the water to get to the beach (Ivan and Murphy 2005). The electric fences constructed in South Dakota included 25 m of extra fencing that extended into the water to a depth of 1 m (Mayer and Ryan 1991). In both cases, electric fences were proven to be very effective in deterring mammalian predators. Mayer

and Ryan (1991) suggest use of electric fences throughout habitat where Piping Plover reproductive success is limited by mammalian predators.

Mammalian predators are often disregarded to due lack of direct evidence. Avian predators are easily identified due to their diurnal behaviour and are easily noticed, while there is a lack of field evidence for mammalian predators (Ivan and Murphy 2005). Many studies suggest mammal and avian predators are preying on both Piping Plover eggs and chicks. Mayer and Ryan (1991) concluded that nest predators were of 65% mammalian and 35% avian, while the chick predators were mostly avian (Ivan and Murphy 2005). It is important to have management that addresses the egg and chick phase in order to boost productivity (Ivan and Murphy 2005). Therefore, strategies must be implemented that take both avian and mammalian predators into account.

2.5 Removal and reduction

Other possible techniques include reducing denning habitat for various mammalian species (Ivan and Murphy 2005), controlling avian populations (Lauro and Tanacredi 2002), and predator removal (Koch 1999). Removing dens of coyotes and foxes in areas surrounding plover habitat can encourage predators to den elsewhere (Schmelzeisen et al. 2004). A method for reducing populations of American Crows is the removal of tall shrubs and trees, which can be used as roosting and perching sites (Ivan and Murphy 2005). Other techniques to reduce predation are directly removing or reducing predator numbers. A method used to reduce gull populations on North Monomoy Island, Massachusetts, used harassment, nest and egg destruction, shooting, and limited used of the avicide DRC- 1339 (Keane 2002). While lethal removal of avian predators is ethically debatable, removal of gulls was found to prevent gull nests establishment and increased Piping Plover nesting (Koch 1999). Trapping of predator

species has had mixed results: nest trapping of gulls in the Massachusetts Piping Plover recovery project proved successful but, trapping of coyotes was largely unsuccessful (Koch 1999). Methods of predator removal are invasive to particular species, are labour- intensive and are only short- term solutions (Patterson et al. 1991; Schmelzeisen et al. 2004). However, they seem warranted in situations where gull colonies have a large population size and predation by gulls is a leading factor of egg and chick fatality.

2.6 Current recovery strategies

Current strategies aimed at increasing the productivity of the Piping Plover at Kejimkujik Seaside focus on reducing human disturbance at nesting beaches (Goossen et al. 2002; Park Canada 2009). This is primarily achieved through awareness and conservation zones. Conservation zones are used during late April to early August in which nesting habitat is closed off to the public (Goossen et al 2002). Park employees are responsible for monitoring and documenting the reproductive success of plovers at St. Catherines River Beach (Parks Canada 2009). They are also responsible for the education and enforcement of conservation zones, as well as education about plovers and recovery strategies (Parks Canada 2009). In 2002, dense mats of beach grass were removed in an effort to restore plover nesting habitat (Parks Canada 2009). This proved effective due to the successful fledging of several chicks in the area (Parks Canada 2009).

Predator exclosures were used at St. Catherines River Beach and were monitored by park employees for evidence of predation (Parks Canada 2009). Predation was usually determined to be from avian predators, however, most instances of predation were not witnessed (Parks Canada 2009). Predator exclosures are no longer used at Kejimkujik Seaside, although the risk of predation is still there and plovers need sites relatively secure from predators. In order to

effectively maintain the population of Piping Plovers, monitoring and mitigation of predators is essential.

2.7 Conclusions

Throughout the literature review it was found that predation is a major factor causing low productivity, both during the egg and chick phase. Therefore, in order to increase the reproductive success of the plover at St. Catherines River Beach, predation management that addresses both phases needs to be considered. The first step in determining what management techniques are most appropriate is to find out the causes of predation, usually inferred from tracks left behind. Many instances of predation are site-specific and vary between avian and mammalian predators. This study will address the make-up of the potential predator community at St. Catherines River Beach in order to better understand what measures need to be in place to protect plover eggs and chicks. In order to maintain a high degree of protection, recovery strategies need to address all potential threats to plover productivity.

While current strategies at Kejimkujik Seaside are effective in limiting human disturbance, increasing awareness, and restoring habitat, there has been no protection of plover eggs and chicks against predators. Nest exclosures are an effective means to increase the reproductive success of plovers; despite this there have been instances of nest abandonment at St. Catherines River Beach. Exclosures can sometimes draw the attention to the plover nests and breeding adults (Vaske et al. 1994). This poses a threat to the adult plover which can result in nest abandonment and egg loss. In order to improve predator management techniques, other options should be considered in the recovery plan. Electric fencing to deter mammalian predators, removal of dens and perching sites, and lethal removal of gull species are all techniques that are viable options for Kejimkujik Seaside. The best method of approach is a

variety of strategies that take all potential predators into account and monitors the effectiveness of these strategies.

3.0 Methods

In order to better understand what could possibly prey on the Piping Plover, research was conducted in early June before going out in the field. This was done by analyzing Kejimkujik National Park Seaside Adjunct resource descriptions which detailed the abundance of different species found throughout the park. From the data, a list was obtained of the most abundant predator species that could potentially be a threat to the Piping Plover. These subjects consisted of avian and mammalian predators. This list was placed at the bottom of the predator identification cards used for recording evidence.

Observation studies were later conducted in early June to November, in order to determine what species comprise the community of potential predators of the Piping Plover at St. Catherines River Beach. Methods were adapted from existing observational procedures at Kejimkujik Seaside.

3.1 Study area and research tools

Observational surveys were conducted 2-3 days per week from 25 June to 30 September 2009 on St. Catherines River Beach located in Kejimkujik Seaside (figure 1). Additional surveys were conducted twice in the months of October and November 2009. St. Catherines River Beach is 1.4 km long and 75-500 meters wide (Cairns 1982). The area consists of an open, sandy beach with cobblestones and scarce vegetation. The beach has a sand dune system and lagoon, of which is surrounded by softwood and mixed wood forests. Kejimkujik Seaside also contains 200 m of artificial habitat (management area) created by park employees in an effort to enhance plover breeding sites, which is located behind the eastern end of St. Catherines River Beach.

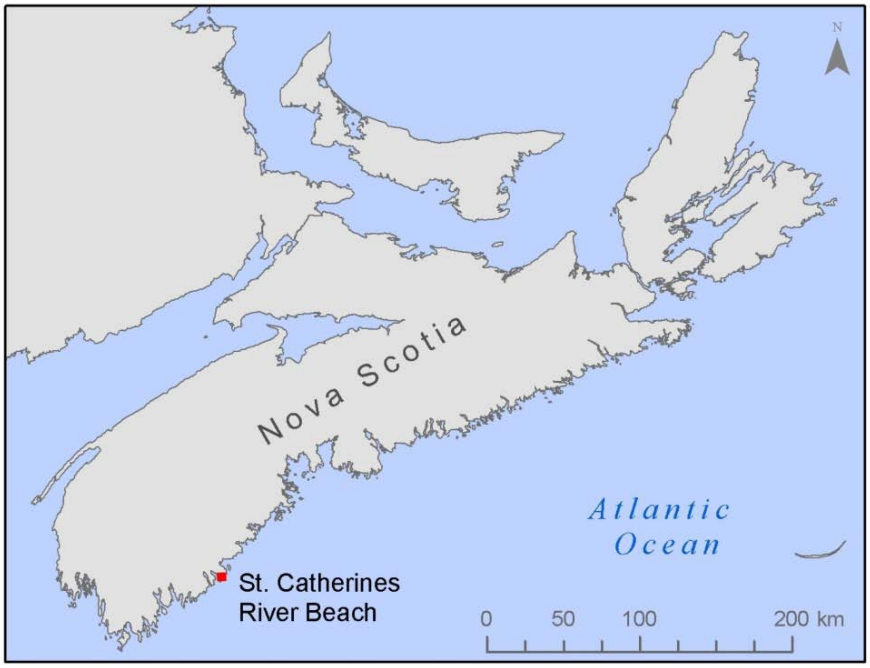

Figure 1. Map of Nova Scotia showing location of St. Catherines River Beach, located in Kejimkujik Seaside. (from NRC 2009).

The research tools used were 1) a glass thermometer with stain-less steel casing, obtained from the Species at Risk Office at Kejimkujik National Park, 2) a ruler for measuring tracks and scat, 3) a map with a specific UTM grid for St. Catherines River Beach, 4) an animal tracks of Atlantic Canada booklet (Sheldon and Eder 2000), that contains pictures of predators, their tracks and measurement scale, and 4) a predator evidence card to allow direct and indirect evidence of predators to be recorded in a efficient manner (appendix 1).

3.2 Procedures

This study was conducted with the help of two Parks Canada employees from 25 June to 28 August 2009. Date, start time, wind speed, precipitation, percent cloud coverage, tide, air temperature and observer names were recorded. The survey started at the beginning of the protected Piping Plover habitat, located at the entrance of St. Catherines River Beach and ended when the researchers finished inspecting the lagoon on the eastern end of the beach; survey

walks were approximately 2 km in length. The management area was inspected at least once a week after the plover adults and chicks residing in the area relocated to the main nesting habitat on the beach. Researchers conducting the survey walked along St. Catherines River Beach approximately 50 m from the dune, in order to avoid disturbing the plovers. After, the plovers had fledged their young in August researchers were able to walk 20 m closer to the dune. Direct (visual) and indirect (tracks/scat) evidence was recorded whenever observed, as well as the UTM easting and northing coordinates for the location, if available. For example, if a Herring Gull was spotted, this was recorded by the abbreviation HERG, then the number observed was noted, the UTM easting and northing coordinates were taken and any additional comments about the location or the predator's behavior. If the type of predator was not available in the predator key located at the bottom of the identification card, other (OT) was selected and the species name was recorded in additional comments. It was not always possible to determine the type of species from the tracks or scat, and it was often difficult to distinguish between coyote, dog, and fox tracks. In these circumstances, photographs were taken for further analysis. Animal tracks and scat guides were used to confirm predator detection. If identification of the canid was not possible, the predator species was identified as unknown canid. When tracks were found to be similar, usually between dog and fox tracks, a simple method of identification was used (figure 2).

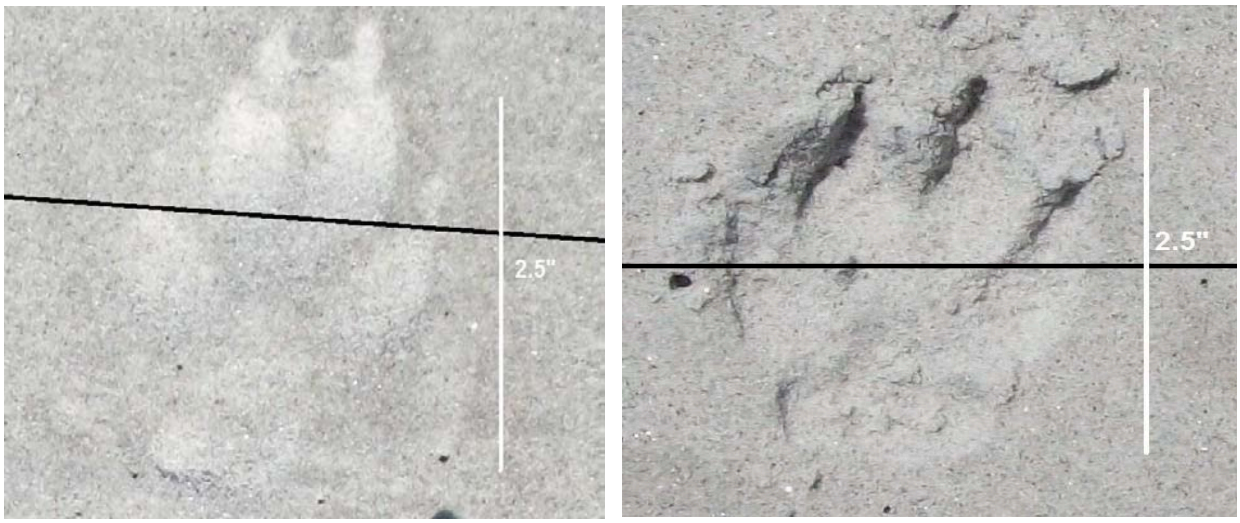

Figure 2. Photograph of red fox (left) and dog (right) track. In order to determine the difference between the two the toe pads need to be examined. The fox's two central pads are farther forward than on dog prints. If you draw a line across the front edges of the outer toe pads, the line will just touch the back edges of the two central toe pads of the fox (Bang et al. 2001).

3.3 Data analysis

Data were analyzed to determine what potential predators are found at St. Catherines River Beach. The data were complied into an Excel spreadsheet and individual sightings tallied. The data were standardized to number of potential predator sightings per hour to give a relative measure of what potential predators are using St. Catherines River Beach.

The data were analyzed to examine variation in predator activity with time of season and lunar cycles. Predator evidence was mapped for June and July in order to determine spatial patterns. Results were interpreted to suggest what predator exclusion techniques would be appropriate given the number of potential predators of particular species and the location in relation to the Piping Plover nesting habitat.

3.4 Limitations and delimitations

Due to lack of time and resource constraints, seasonal effort was uneven. Data obtained during the months of October and November was only obtained twice a month. Due to setbacks

in the creation of the UTM grid map, the location of all potential predator detections was not recorded. Furthermore, weather conditions, such as heavy rain the night before the observational study disturbed tracks making it difficult to identify species. Other species identification constraints occurred due to the lack of certain individuals leaving behind a clear foot impression.

The method used in determining potential predators was adapted from procedures used at Kejimkujik Seaside; if any evidence of predation was observed by park employees directly it was recorded. I expanded on this general approach to include track and scat evidence of predator species that could potentially pose a threat to plover productivity.

4.0 Results

4.1 Seasonal variations of potential predators

Avian predators were the most frequently observed potential threat to the piping plover at St. Catherines River Beach. The Herring Gulls and Great Black-backed Gulls were the most common avian species observed. Herring Gulls numbers remained relatively constant throughout the study. The Great Black-backed Gull was less commonly seen during the months of October and November. The number of American Crows observed increased during September, October, and November.

The most prominent mammalian species observed was the red fox and unidentified canid. The number of red foxes increased during the fall months and especially after park employees had left in late September. The number of coyote, raccoon, bobcat, and American mink evidence observed was very limited throughout the entire study period.

Table 1. Potential predator evidence from June to November.

Predator	Total No. of detections	No. of detections/hr					
		Jun	July	Aug	Sept	Oct	Nov
Herring Gull	445	5.63	4.19	6.74	8.27	5.60	3.29
Great Black-backed Gull	151	4.38	2.16	1.61	1.64	1.20	1.57
American Crow	69	0.31	0.36	0.48	1.64	2.00	2.57
Bald Eagle	5	0	0.13	0.04	0	0	0
Unknown Canid	27	0	0.29	0.22	1.00	0.40	0
White-tailed Deer	11	0	0.16	0.13	0.18	0.20	0
Red Fox	24	0	0	0.09	0.64	1.20	0.73
Dog	5	0	0	0.13	0.09	0	0
Raccoon	2	0	0.06	0	0	0	0
Coyote	3	0	0	0.04	0	0	0
Bobcat	1	0	0	0	0	0	0.14
American Mink	2	0	0	0	0.09	0	0
Total No. of hours		4.00	30.00	27.50	10.50	6.00	7.35

4.2 Variations with the lunar cycle

Variation within the lunar cycle was observed in relation to potential predator detections. Potential predators that had limited detections were left out of lunar analysis, with the exception of the coyote. The lunar data that pertains to white-tailed deer, dog, bald eagle, raccoon, bobcat, and American mink are found in Appendix 3.

The number of detections of Herring Gulls was roughly consistent throughout the observed lunar cycles. During the last quarter is when the most Herring Gulls detections were observed. Also, the Herring Gull was consistently detected during the new moon and full moon cycles. The number of Great Black-backed Gull detections varied throughout the lunar cycles. During the first quarter cycle is when the most Great Black-backed Gull detections were observed. However, the Great Black-backed Gull was observed consecutively throughout the full moon cycle.

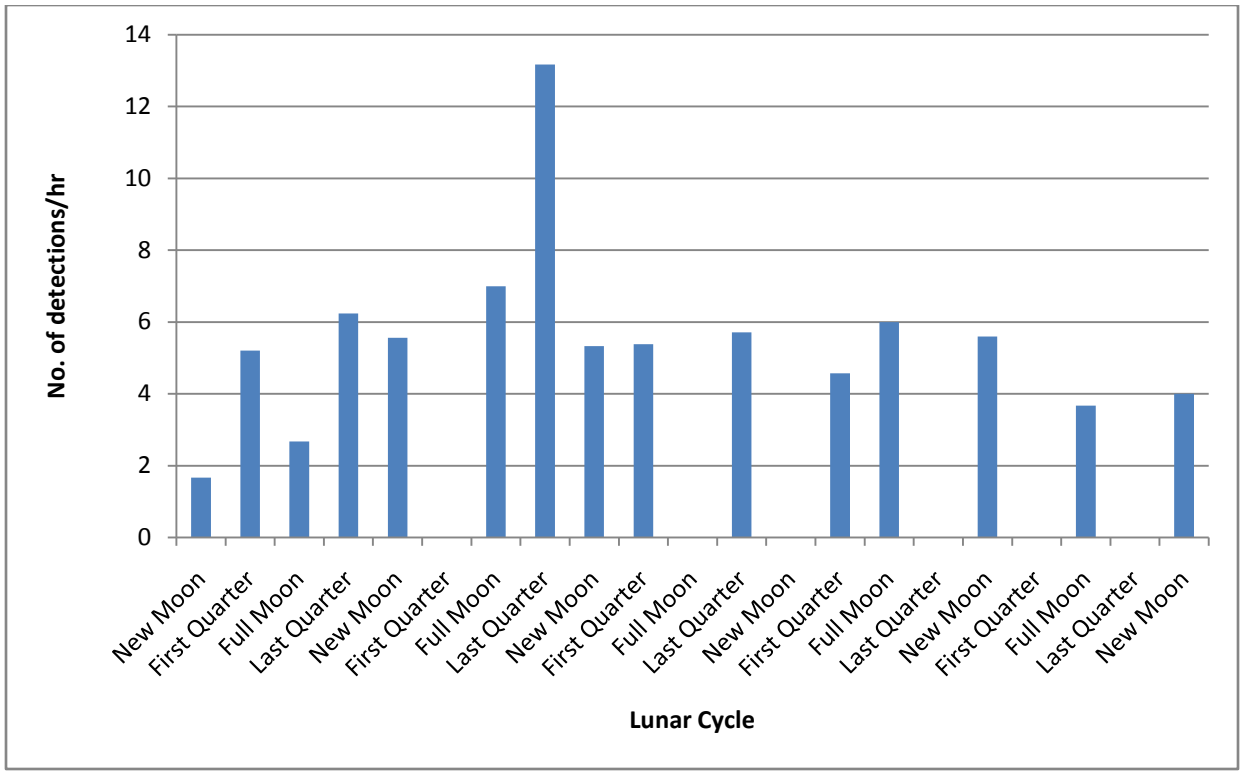

Figure 3.Lunar cycle variations in relation to the Herring Gull.

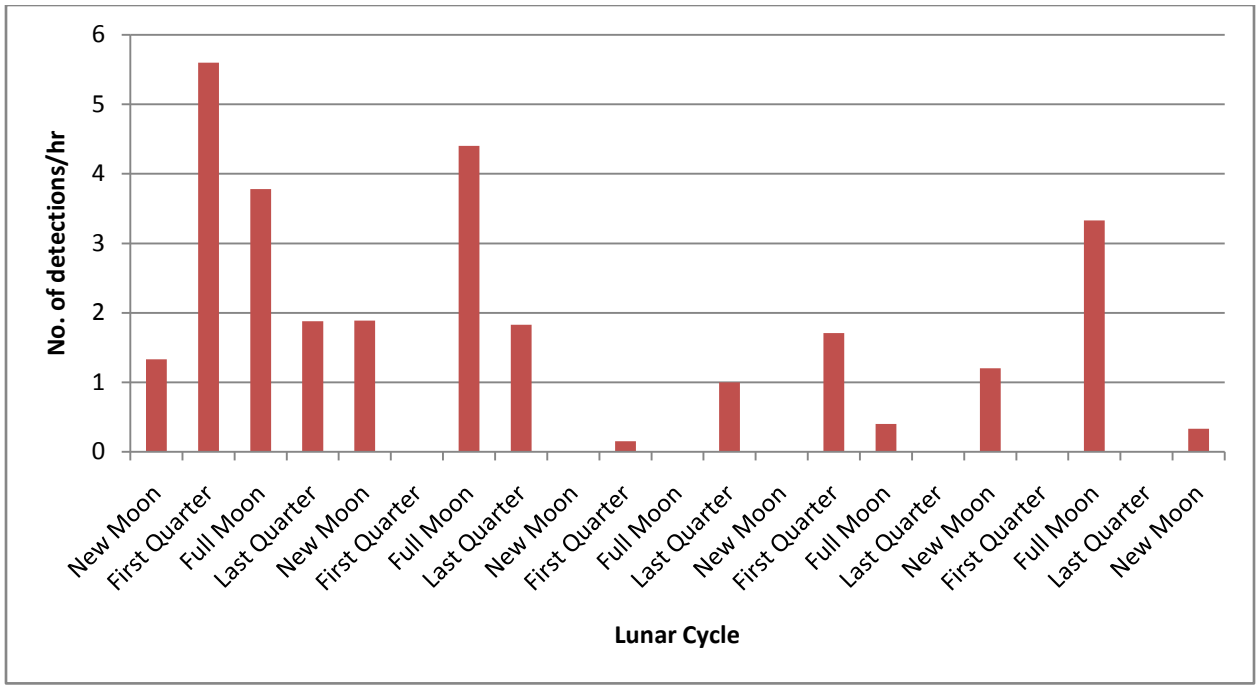

Figure 4. Lunar cycle variations in relation to the Great Black-backed Gull.

The detections of the American Crow appear to vary over the lunar cycles. The crow was detected the most during the full moon cycle in November. It was also detected most readily during the full moon cycles of August and September, and the new moon cycle in November.

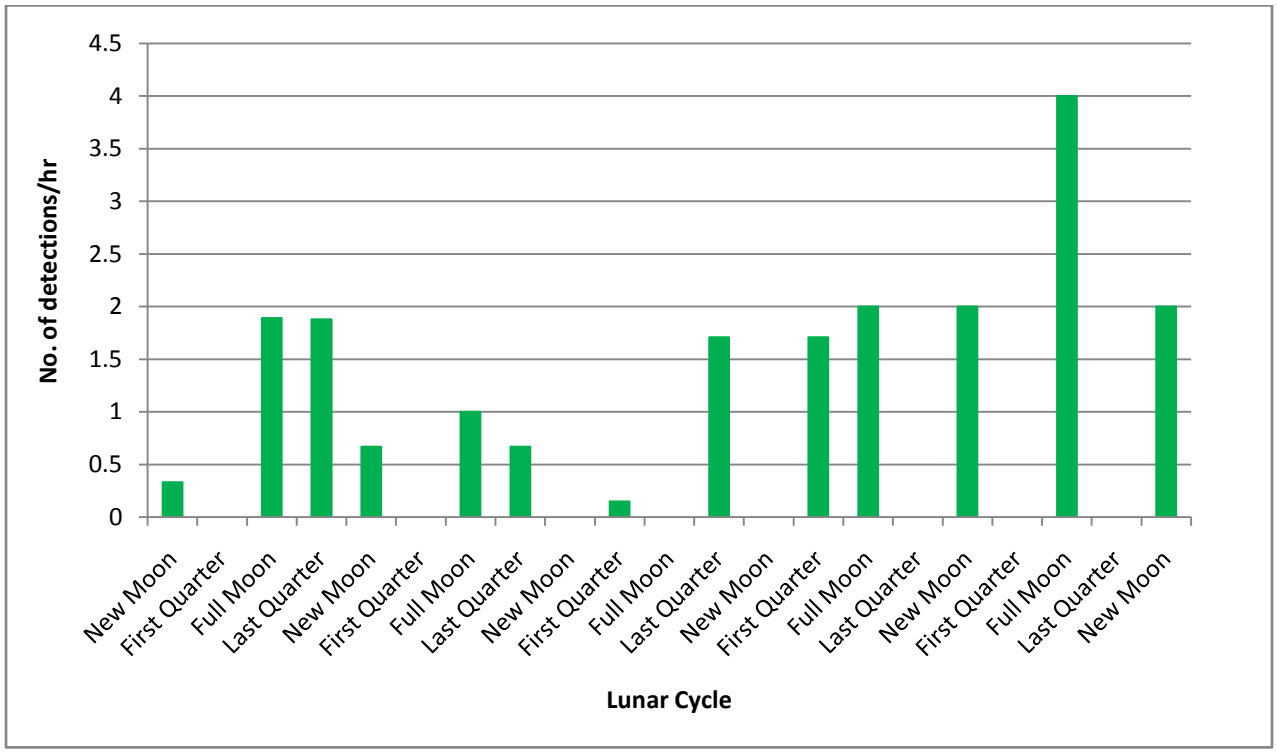

Figure 5. Lunar cycle variations in relation to the American Crow.

The detections of unknown canid occur the most during the full moon cycle. There is also number of detections throughout the last and first quarter. Detections of red fox occur the most during the full moon cycle. For example, the red fox detections are 2.67/hr during the full moon cycle and 0.33/hr during the new moon cycle in November. For the coyote, 2 out of 3 of the confirmed coyote detections were recorded during the full moon cycle. The other detection was observed during the last quarter.

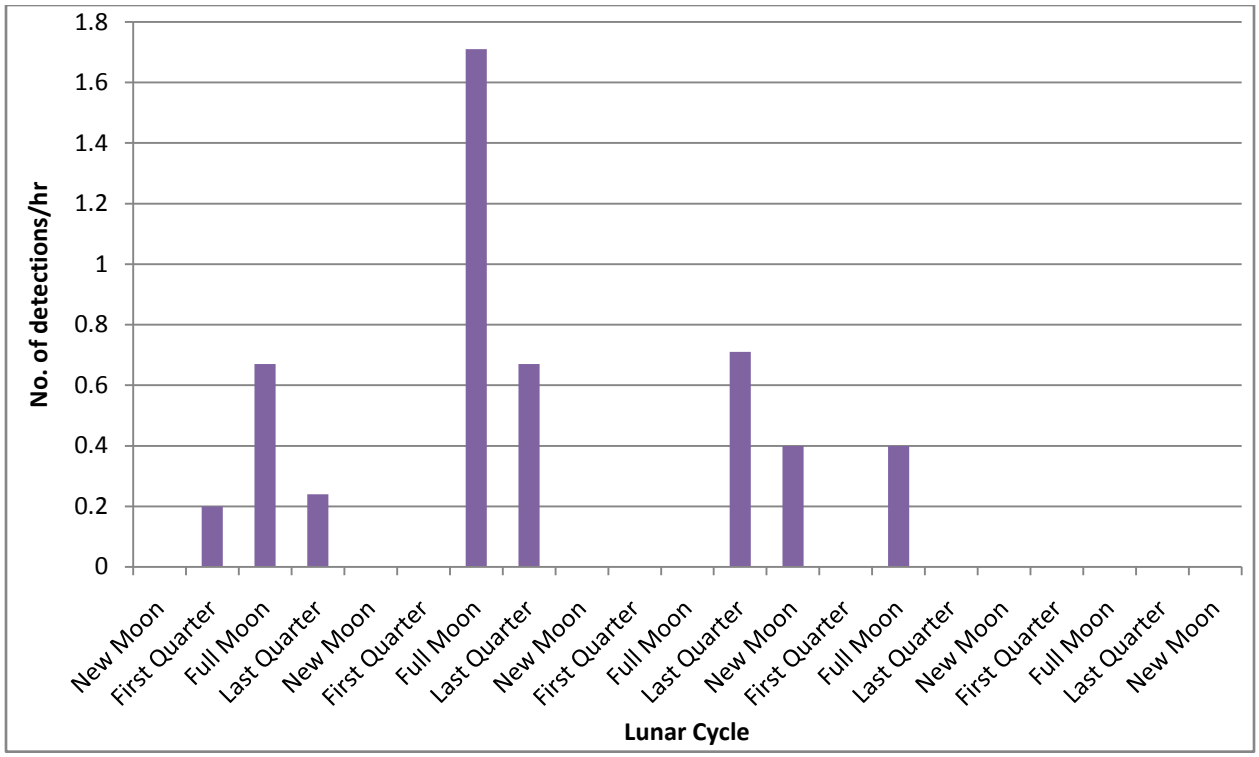

Figure 6. Lunar cycle variations in relation to unknown canid.

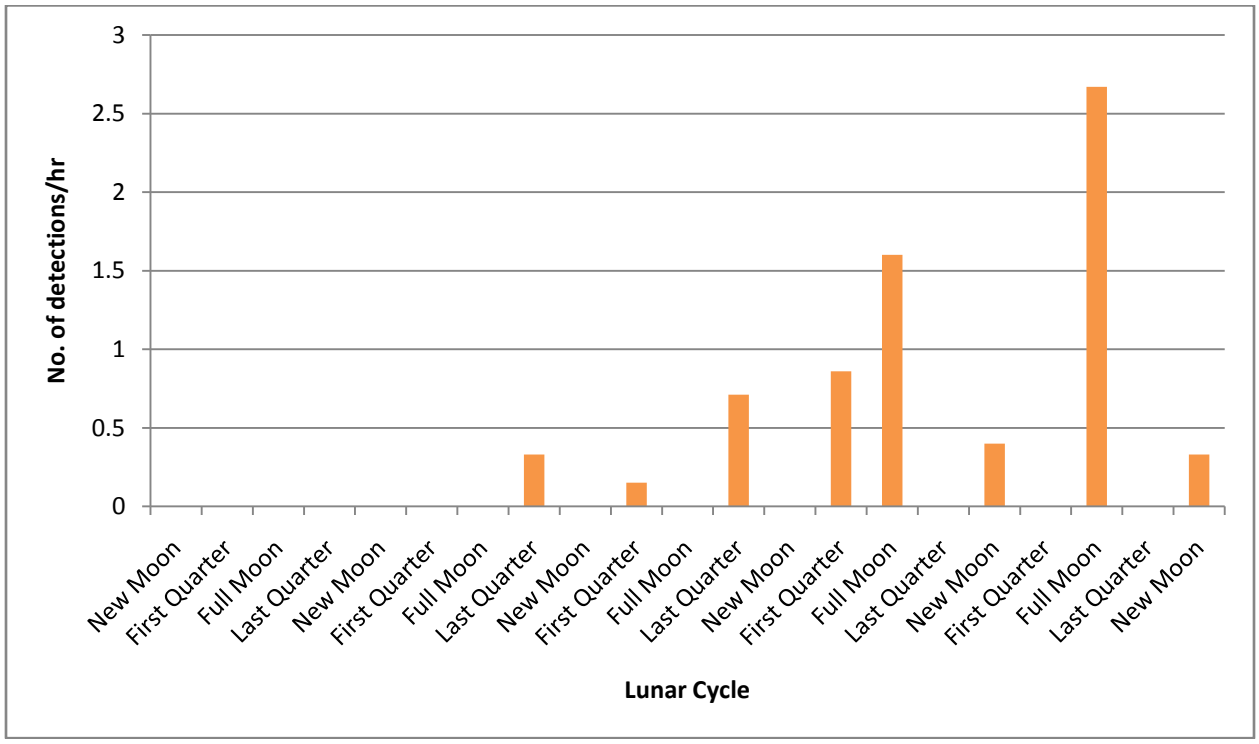

Figure 7. Lunar cycle variations in relation to the red fox.

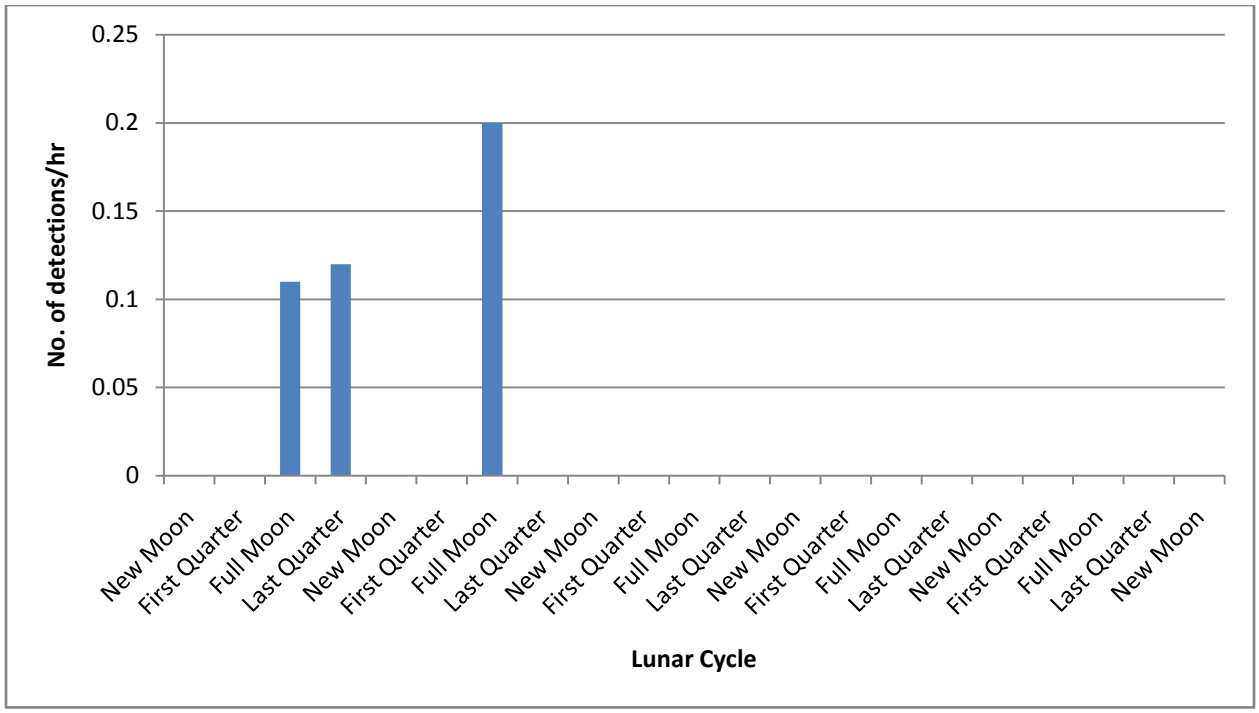

Figure 8. Lunar cycle variations in relation to the coyote.

4.3 Spatial variations of potential predators

During June and July, potential predators detected were: Herring Gull, Great-Blacked Gull, American Crow, and unknown canid. It is during this period that the Piping Plover has already established nests on St. Catherines River Beach. Predator detections of the Herring Gull and Great Black-backed Gull vary in relation to the nests of the plovers. American Crow detections were observed near the wooden area of the lagoon located in close proximity of the failed plover nests. Unknown canid detections were found near the entrance to St. Catherines River Beach, in the lagoon area, and in the management area. The unknown canid evidence was detected in close proximity to one of the hatched nests. However, this nest was successful in fledging its young. The two nests that failed were located farther up the beach, and were in an area used by all potential predators.

Figure 9. Potential predator detections in relation to Piping Plover nests during June and July on St. Catherines River Beach (from AGRC 2007).

5.0 Discussion

The following species comprised the community of potential predators of the Piping Plover at St. Catherines River Beach: Herring Gull, Great Black-backed Gull, American Crow, Bald Eagle, unknown canid, white-tailed deer, red fox, dog, raccoon, coyote, bobcat, and American mink. This is consistent with the various studies that determined known or suspected predators of plover eggs and chicks, with the exception of the Bald Eagle and the bobcat. Evidence of avian species was primarily found through direct observation of the birds, whereas evidence of mammalian species was found through indirect observation of tracks and scat. The results of this study are consistent with Ivan and Murphy's (2005) findings that evidence of avian predators is easily obtained due to their diurnal behaviour, while evidence of mammalian predators is more difficult to obtain and usually indirect.

5.1 Seasonal variations

The results showed little to no seasonal variation in Herring Gull numbers. The number of detections remained relatively constant through the summer to fall transition. This result is consistent with the information obtained from Kejimkujik National Park Seaside Adjunct resource analysis which states that Herring Gulls and Great Black-backed Gulls are abundant during all seasons (Farrier et al. 1991).

The results suggest that American Crow detections increase during the fall months. McGowan (2001) states that crows tend to leave their territories for longer periods of time during the fall and winter in order to forage and roost in aggregations. This could explain why there was

an increase in American Crow detections in the fall. Tufts (1973) suggests that the American Crow is most commonly observed in autumn. This is consistent with the number of crow detections increasing during September, October, and November.

Another avian species found was the Bald Eagle. These sightings were few and took place during the months of July and August. These results are consistent with the resource analysis of Kejimkujik National Park Seaside Adjunct which states that the Bald Eagle is a very rare visitor to the park (Farrier et al. 1991). The Bald Eagle is not considered to be a significant threat to the Piping Plover because of its rare occurrence and the fact that it rarely attacks live prey (Tufts 1973).

The red fox was detected in August, September, October, and November with the majority of detections occurring in the fall months. This may be due to the fact that foxes are wary of humans (Sillero-Zubiri et al. 2004). Fox detections on St. Catherines River Beach increase when park employees are off-season in late September and visitation to the beach is minimal. Foxes in heavily populated areas were found to be more tolerant of human presence, while others may avoid any human contact entirely (Sillero-Zubiri et al. 2004). The findings of this present study suggest that red foxes residing near St. Catherines River Beach avoid human contact. A study conducted in Cape Cod, Massachusetts, determined that fox track density increased with more intensive human use of the beaches (Strauss 1990). The study conducted by Strauss appears to be inconsistent with the study conducted at St. Catherines River Beach. This is possibly due to the fact that foxes near Cape Cod need to adapt to a constant human presence in their habitat, while the habitat at St. Catherines has little human disturbance from late September to early May. St. Catherines also has little to no human settlement in close proximity to the beach, while Cape Cod has been settled heavily by humans. It is possible that fox track density

varies with human presence on an annual basis.

Another mammalian potential predator observed was the coyote. It was confirmed to be present twice in July and once in August. This was determined by identifying scat left behind on trails. This result is consistent with the fact that coyotes often leave their droppings on trails to mark territories (Bang et al. 2001). The detection of coyotes was verified three times throughout the study. There were numerous occasions that unknown canid evidence was recorded that were thought to be coyote tracks, however it could not be verified due to the presence of dogs or lack of a clear print. Coyote and dog tracks are very similar, which made identification problematic.

Mammalian species that had limited detection were the raccoon, bobcat, and American mink. The raccoon was observed in July, the bobcat in November, and the American mink in September. Kejimkujik National Park Seaside Adjunct resource analysis records all of these species as common (Farrier et al. 1991). The limited detections of bobcat could be because their habitat is more closely related to forest streams, lakes, forest edges, and mixed forest (Farrier et al. 1991). Raccoons and minks occupy a wide range of habitats which may explain their limited detections. Although, both mammals prefer wooded habitat near water, such as stream banks, shores of lakes and ponds, and ocean shores (Farrier et al. 1991).

5.2 Lunar cycle variations

During all lunar cycles, the Herring Gull is found to be the most predominant potential predator. The number of detections of Herring Gulls was roughly consistent throughout the observed lunar cycles, with the exception of an increase in detections during the last quarter in August. There is no evidence to suggest that the Herring Gull is present more often in any of the lunar cycles. However, this was not the case for the Great Black-backed Gull.

It was determined that Great Black-backed Gull detections were observed more readily

during the full moon cycle. At this time, Great Black-backed Gulls may take advantage of the increased moonlight in order to predate plover eggs and/or chicks. Nelson (1989) determined that Cassin's Auklets *(Ptychoramphus aleuticus)* on Southern Farallon Island in California were predated more readily on moonlight nights than on dark nights. The study concluded that Western Gulls (*Larus occidentalis*) were responsible for most of the killed juvenile and adult auklets (Neslon 1989). Nocera and Kress (1996) observed Great Black-backed Gulls preying upon Common Tern *(Sterna hirundo)* chicks and eggs during the night, in which light from the moon was visible. It was found that a Great Black-backed Gull entered a tern colony and was met by some mobbing terns, although the mobbing behaviour was less persistent than during the daylight (Nocera and Kress 1996). A necropsy revealed that the gull had consumed 3 chicks and five tern eggs (Nocera and Kress 1996). It was determined that Great Black-backed Gulls are able to forage for food up to 24 hours, during a wide range of light conditions (Nocera and Kress 1996). Great Black-backed Gulls have been detected the most during the full moon cycle and could use the moonlight in order to predate plover eggs and chicks. In order to appropriately protect the plovers, the full moon cycle needs to be taken into account with respect to the patterns of predation of Great Black-backed Gulls.

The results indicate that the detections of American Crow fluctuate throughout the lunar cycle. There appears to be an increase in detections during the full moon cycle in October and November. However, detections of the American Crow increased during the fall months regardless of the lunar cycle. Therefore, there is no trend that is associated with the crow and a specific lunar cycle.

Potential predator detections of unknown canids occur most frequently during the full moon cycle. This is also the case for other mammals, such as the red fox and the coyote. Activity

levels are altered due to light intensity indirectly acting upon the nervous system through retinal photoreceptors (Kramer and Birney 2001). The risk of predation by nocturnal animals, such as the coyote and the red fox, is likely to be enhanced during periods of higher light intensity (Kramer and Birney 2001). This study is consistent with the findings that canids are more active during the full moon cycle. This increase in light allows the coyote or red fox to be more active than they would be during a quarter moon cycle.

5.3 Spatial variations

The months of June, July, and August are most critical in this study because Piping Plovers return to their breeding grounds on St. Catherines River Beach during late April or May and remain there until mid-August (Cairns 1977). The plover chicks spend a month in the egg and a month foraging for food before they can fledge (Goossen et al. 2002). In May 2009, 10 adult plovers were detected at St. Catherines, of which 3 were pairs (D. Smith, personal communication. March 29th, 2010). The first nest, located closest to the entrance of St. Catherines, was successful in hatching 4 eggs on 3 June (D. Smith, personal communication. March 29th, 2010). However, only two of these chicks fledged later in July (D. Smith, personal communication. March 29th, 2010). This nest was located approximately 500-600 m from the entrance to St. Catherines River Beach. This area was observed to be one of the most common areas in which Herring Gull and Great Black-backed Gull detections occurred. During June and July, Great Black-backed Gull detections were located near the entrance to the beach more than any other of the observed months.

There was also a detection of unknown canid approximately 200-300 m from the nest. Despite this, the first nest was successful in hatching all of the 4 eggs, only 2 chicks survived and the other 2 were lost to unknown causes (D. Smith, personal communication. March 29th, 2010).

It is possible that due to the close proximity to various potential predators, those 2 chicks were lost to predation. This is consistent with finding that causes of loss during the chick phase are difficult to determine due to lack of evidence (Environment Canada 2006).

The second nest was discovered on 27 May in the management area, located behind the main beach (D. Smith, personal communication. March 29th, 2010). This nest was successful during both egg and chick phases. Although, this nest site was located near observed detections of unknown canids, the pair was successful in fledging all of its young. The young of this nest later moved to the main beach during July.

The third nest was discovered at St. Catherines on 22 May and consisted of 4 eggs, of which all were lost to unknown causes (D. Smith, personal communication. March 29th, 2010). This nest is located at the very eastern end of the beach, in close proximity to a detection of unknown canid. This area is also very commonly used by American Crows, Great Black-backed Gulls, and Herring Gulls. Although, the nest was regarded as failed due to unknown causes, it is feasible to suggest that this nest could have been predated due to common use of the area by various potential predators.

The fourth nest was a re-nest attempt by the pair whose nest was lost to unknown causes (D. Smith, personal communication, March 29th, 2010). This nest was discovered on 9 June with 1 egg and was lost on 10 June to gulls confirmed by tracks nearby the nest (D. Smith, personal communication. March 29th, 2010). This nest is in close proximity to detections of raccoon and American Crows. It is also adjacent to the colony of gulls that exist in the lagoon area of St. Catherines River Beach. Throughout the entire study period, this area has been noted to contain the most detection of the Herring Gull and the Great Black-backed Gull. Gulls pose a significant threat to the eggs and chicks. In order for reproductive success to increase in this area

management techniques that deter these avian predators need to be employed.

6.0 Conclusions and recommendations

Detections of potential predators were largely avian species, especially the Herring Gull, Great Black-backed Gull, and American Crow. The potential mammalian predator that was detected most often was the red fox. Other mammalian species that could pose a threat to the productivity of the plovers, but were detected rarely, were the raccoon, bobcat, American mink, and coyote. There was a fair amount of unknown canid detections observed during July which could limit fledging success. Future management should include techniques that minimize the impact of both avian and mammalian predators. Although, avian predators were detected more often than mammalian predators, this is perhaps due to the ease with which they were observed. Mammalian species, although more often detected during the months in which the plover chicks have fledged, should not be excluded in predation management.

The pressure of avian potential predators was constant throughout the study period and presence of these predators was found to be in close proximity to the nesting sites during the months of June and July. Management techniques such as predator exclosures should be encouraged at St. Catherines River Beach. Predator exclosures have been successful in protecting the nest to the hatching stages in Atlantic Canada (Corbett 1997), the Atlantic coast of the United States (Rimmer and Deblinger 1990), and the northern Great Plains (Murphy et al. 2003a). It is imperative that discreetness be taken when using exclosures due to nest abandonment and egg loss that has occurred in the past. The exclosures should be constructed and removed as quickly as possible in order to avoid drawing attention to the eggs and reducing the amount of time the incubating plover is off the nest. Vaske et al. (1994) determined that nest abandonment was greatest for small, circular exclosures (< 300,000 cm^2) without fence posts. It was also

determined that nest abandonment did not occur at exclosures without covers (Vaske et al. 1994). If nest exclosures are too be applied at St. Catherines River Beach, they should be large (30,000-60,000 cm^2) and square shaped cages with fence posts. In order to ensure that the nest exclosures stays in place, fence posts of metal or wood (1.2-2.5 m) should be applied (Vaske et al. 1994).

Due to the amount of evidence of unknown canid, as well as detections of raccoon, coyote, and red fox during the period when the plovers occupy St. Catherines River Beach, predator management should include techniques that deter mammalian predators. During July, there is presence of unknown canids and raccoons on St. Catherines River Beach. In order to discourage these predators, electric fencing is a viable option. Electric wire or spikes must be present on top of the fence and it should be as low as possible to discourage perching of avian predators (Schmelzeisen et al. 2004). Mayer and Ryan (1991) constructed electric fencing at the base of a peninsula in South Dakota. The cost of fencing material was $1.20/m US, with replacement of corroded wise mesh at $0.66/m US and a construction time of 48 hours/fence (Mayer and Ryan 1991). Electric fencing offers many advantages over predator exclosures: construction is prior to the arrival of plovers, maintenance is required only to inspect electrical system and remove vegetation along the fence, and it is left in place year after year (Mayer and Ryan 1991). The employment of electric fences along St. Catherines River Beach is recommended in conjunction with predator exclosures to further protect the population of Piping Plovers.

Reduction of nearby fox and coyote dens is a cost-effective way to reduce mammalian potential predators of the plover. However, trapping of these individuals has proven to be largely unsuccessful (Koch 1999) and is not recommended. The removal of trees near typical Piping Plover habitat is a viable option to reduce potential roosting and perching sites for American

Crows. A study conducted by Preston (1957) observed crows perched in trees were predating nearby Mallard *(Anas platyrhynchos)* nests. The crows observed the movements of the adult ducks in order to determine where the nest was located and predated the eggs (Preston 1957). American Crows were found to be present in a few trees and in the woods near the entrance to St. Catherines River Beach. In order to facilitate the plovers, perching sites that are in close proximity to plover nesting habitat should be removed. Other methods of reduction and removal, such as the lethal removal of gulls are not recommended as a suitable action due to ethical concerns. Predator removal using live trapping can be used for gulls or other predators that are frequently found utilizing St. Catherines River Beach, however traps must be inspected regularly and individuals should be marked to ensure whether or not they return.

6.1 Future research

This study contributes to the knowledge of potential predators of the Piping Plovers at St. Catherines River Beach. In addition to this, information pertaining to seasonal, spatial, and lunar variations of potential predators at St. Catherines was generated. This information can be used to enhance protection of Piping Plover eggs and chicks at Kejimkujik Seaside. Effective management of predators should be influenced by the identification of potential and known predators of plover eggs and chicks. The use of predator identification cards is an efficient way to record information. However, improvement is needed in the method of identification.

To facilitate learning of potential predators, park employees should be given an animal track and scat guide of Atlantic Canada. When tracking, it is important to know that most tracks remain only for a short period time and the state of the tracks are largely dependent on the surroundings. The best conditions to observe tracks along the coastline are during low tide, when the sand it slightly wet (Bang et al. 2001). When observing tracks along the sand dune, the best

conditions are during early morning while the sand is still wet with dew (Bang et al. 2001). Also, when tracking it is important to take habitats into consideration in order to determine the difference between similar species (Sheldon and Eder 2000). To increase the chances of identifying animal tracks correctly, the use of track plates is advised. Track plates are an inexpensive and effective way to verify mammalian carnivores in a particular area (Barrett 1983). They consist of an aluminum sheet with a patch of soot or ink, a slightly tacky white sheet of paper placed at the distal end of the aluminum sheet, and bait, such as fish oil (Barrett 1983). Many track plates are enclosed in single-entrance boxes to ensure the protection of prints from the weather (Barrett 1983). If seeking the tracks of a specific animal, the placement of the track plate should be in the known habitat of that species.

Future studies of gulls and crows, as well as other depredating species populations should be considered. In order to obtain a less-biased estimate of predator populations, transect sampling should be examined. This type of sampling is used to acquire viable animal abundance estimates by measuring the perpendicular distance between the animal detection and the transect line (Melville and Welsh 2001). Other areas of future research include the distribution of predators during early April and May. This could be used to better understand spatial variations of predators when nests are most vulnerable to predation. Finally, further research should consider variations in predator detections during specific lunar cycles in order to confirm if there is a correlation between light intensity and risk of predation. Overall, creative and innovative methods of predator detection and management are needed in order to maximize fledging success of the plovers.

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Appendix 1: Predator identification card, includes list of potential predator species found commonly throughout Kejimkujik Seaside.

PREDATOR IDENTIFICATION CARD

Date:(d)___ - (m) ____ - 2009 Start time: _______End Time: ______ Wind Speed*: ____Precipitation*: ____% Cloud Coverage: _____
Observer(s): _____________________________________ Tide*: _____☐ moving in ☐ moving out Air Temperature: _____

Predator*	**# Observed**	**Evidence***	**UTM East**	**UTM North**	**Additional comments**
			35 __ __ __ __	48 __ __ __ __ __	
			35 __ __ __ __	48 __ __ __ __ __	
			35 __ __ __ __	48 __ __ __ __ __	
			35 __ __ __ __	48 __ __ __ __ __	
			35 __ __ __ __	48 __ __ __ __ __	
			35 __ __ __ __	48 __ __ __ __ __	
			35 __ __ __ __	48 __ __ __ __ __	
			35 __ __ __ __	48 __ __ __ __ __	
			35 __ __ __ __	48 __ __ __ __ __	
			35 __ __ __ __	48 __ __ __ __ __	
			35 __ __ __ __	48 __ __ __ __ __	

Tide*
L = Low H = High /
F= falling R = rising

Precipitation*
N = None M= Moderate– Heavy Rain
D = Drizzle/mist O = Other (specify)
L = Light rain

Wind Speed*
C =Calm M= Moderate
L = Light S = Strong

Evidence*
Visual = V
Tracks = T
Scat = S

Predators*

HERG = Herring Gull
GBBG = Great Black- backed Gull
MERL= Merlin
NOHA= Northern Harrier
AMCR= American Crow
AM= American Mink
RC = Raccoon
BC = Bobcat
RF= Red Fox
CO= Coyote
RO = River Otter
SW = Short- tailed Weasel
SS = Striped Skunk
UB = Unknown Bird
UM = Unknown Mammal
OT= other; write in species