Raptor Mortality and Behavior at Wind Turbines Along the North Shore of Lake Erie During Autumn Migration 2006-2007

by

Kevin Stuart Dance

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Authors Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

During 2006 and 2007 behavioral observations surveys of raptors were conducted at 12 turbines of a 66-turbine wind farm near Port Burwell, Ontario, Canada. Mortality surveys were conducted at all turbines in the wind farm with additional search effort at the twelve turbines where behavioral monitoring was conducted. The wind farm is located along a significant autumn raptor migration corridor along Lake Erie which is in the area of the Central Flyway. Only one raptor fatality was found each year at the 12 turbines used in the study, with one additional fatality found at the other 54 turbines in the wind facility. The estimated mortality rate for Erie Shore Wind Farm ranged from 0.028 to 0.049 raptor fatalities/MW/autumn. The estimated mortality rate for Erie Shores is at the low end of mortality for North American wind facilities outside of California, and which are not located in known migratory pathways. My findings suggest that the presence of high numbers of migrant raptors passing over a wind facility site does not automatically equate to high collision mortality. Over 5,579 observations of individual raptor passes within 250m of a turbine were recorded. The majority of raptors (73%) passed outside of blade sweep height. The majority of raptors avoided entering the risk zone of operational turbines with 2.92% (n = 159) of raptors observed passing within the risk zone of blade sweep height above ground and 0-40m out from the turbine base. The majority (73%) of raptors that entered the risk zone did so under conditions when risk was reduced due to turbine blade orientation in relation to the raptors' direction of movement or when the turbine was not operational.

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Dedication

This thesis is dedicated to my parents, Ken and Janet Dance, and my wife Catherine and son Lochlyn whose support and encouragement have made it possible for me to pursue my goals.

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Chapter 1. INTRODUCTION

Literature Review

The generation of electricity through renewable energy sources has become an ever more common goal of countries throughout the world. A shift in focus from traditional forms of energy generation such as coal-fired energy plants, nuclear power plants and large scale hydro electric dams has taken place for a variety of environmental and social reasons. Reasoning behind the shift from traditional forms of energy generation includes the fear that we have or will soon reach peak oil, at which point oil production will decline and the cost of oil will sky rocket (Campbell 2008). Ever increasing concern and understanding of global climate change and the potential impacts it will have on the earth are other reasons. Traditional forms of large scale energy production are also associated with a variety of negative environmental impacts such as air pollution from coal fired energy plants which affect air quality; release of toxic levels of mercury by hydroelectric reservoirs; immense loss of forest habitat and altering of watersheds by hydro developments and a limited knowledge and ability to store radioactive waste from nuclear reactors for the long-term and the potentially devastating effect nuclear reactors can have if something goes wrong (Source Watch 2009; Health Canada 2009; Paperny 2009).

The desire to shift generation away from traditional forms of energy production is relatively new and the impacts of the various renewable energy sources in some cases are still unclear. Research to identify the impacts of renewable energy is needed to determine the adverse impacts of renewable energies like wind turbines, so they can be minimized where possible, so that we can maximize the benefits of adopting renewable energy sources.

As of January 2008 Canada had a total installed wind turbine capacity of 2,369 MW, which is enough electricity to be able to power 680,000 homes (Canadian Wind Energy Association[a] 2009).

Ontario currently has the greatest installed wind turbine capacity at 782.1 MW and is followed by Quebec at 531.8 MW and Alberta at 523.7 MW (Canadian Wind Energy Association[a] 2009). From 2000 to 2006 the average annual growth rate of wind energy production in Canada was 51%, with the greatest growth in 2006 when 776 MW of capacity were installed, which increased the installed energy capacity in Canada by 113% (Canadian Wind Energy Association[b] 2008).

There were 21 sites in Ontario with wind turbines up and running by the end of 2008, including the second phase of an operational wind farm already generating electricity (Canadian Wind Energy Association[c] 2009). Wind farms in Ontario range in scale from single turbine sites to currently the largest with 126 turbines at the Port Prince Wind Farm in Sault Ste Marie.

The incidental finding of dozens of dead raptors by maintenance crews shortly after the Altamont Pass Wind Resource Area (APWRA) in California was made operational in 1981, started to raise concerns about the ecological effects that wind turbines may have on birds (Smallwood & Thelander 2007; Orloff & Flannery 1992).

Numerous human structures have been estimated to cause greater bird collision mortality than wind turbines. Anthropogenic causes of collision mortality include communication towers, powerlines, vehicle collisions, and buildings/windows and have all been implicated as causing greater avian mortality than wind turbines (Erickson *et al.* 2001; Kuvlesky Jr *et al*. 2007). For example long-term data from five communication towers, indentified an average of 105 to 3285 bird fatalities per year at these structures (Harden 2002). It is estimated that annual avian fatalities due to collisions with human structures ranges from 200-500 million birds (Erickson *et al*. 2001). Based on the estimate of annual avian collision fatalities and the estimated number of wind turbines in the U.S. (15,000 turbines), as of 2001, Erickson *et al*. (2001) estimated that wind turbines constitute 0.01 to 0.02 percent of avian collision fatalities which equates to 1-2 of every 10,000 fatalities. This means that approximately 33,000 birds die annually due to collision with wind turbines (Erickson *et al*. 2001).

The loss of a few individuals from populations due to wind turbines is undesirable, but if the losses are not large enough to affect birds at the population scale, then losses caused by turbines can be expected to be replaced by the surviving population. For example there are approximately 15 million Nashville warblers (*Vermivora ruficappilla*) in ON (Cadman *et al*. 2007); many could be killed without a population-level impact. Still, impacts on endangered, threatened or significant bird species or high trophic level species is a further concern since the loss of a relatively few individuals may be more likely to harm population viability. With golden eagles (*Aquila chryaetos*) for example one hundred deaths might have an impact due to the birds' life history eg. length of time to reach maturity for breeding, long-term pair bonds, few young raised yearly (Sandilands 2005; Bent 1961).

Raptors are a group of birds well known for their visual abilities. Raptors have binocular vision as a result of the location of their eyes on their head, allowing them accurate judgment of distances (Ferguson-Lee and Christie 2001). Other visual adaptations in raptors include seeing in the ultra violet light spectrum, having two foveal regions (allows them frontal vision and to see below them), and good peripheral vision due to a low ratio of reflectors to ganglion cells (Hodos 1990; Ferguson-Lee and Christie 2001). Vultures are well known for their olfactory senses, for example the olfactory bulb of the turkey vulture is known to be large compared to most other birds (Bang and Cobb 1968; Smith and Paselk 1986). But further study is needed on the role that smell plays in raptors hunting or finding carrion. The auditory abilities of raptors are comparable to that of humans, with an upper limit of 10-20 kHz and a low range of 50-300 Hz (Ferguson-Lee and Christie 2001; Dooling 1982). As such, raptors can hear operational turbines, but under certain wind conditions their ability to hear them may be limited (just like a humans) based on wind speeds and wind direction compared to direction of a raptors movement (ie. if a raptor is up wind during high wind speeds the sound of the turbine may be carried away and not heard to the same extent as it would at lower wind speeds).

The degree of collision risk to specific species and even specific bird groups has been raised but to date has been a relatively untested concern (Madders & Whittfield 2006; Western EcoSystems Technology Inc 2000; Drewitt & Langston 2006). Various types of impacts on birds have in recent years been applied to wind farm developments in an attempt to try to understand avian-turbine interaction including displacement due to disturbance, barrier effects, and habitat change and loss (Drewitt & Langston 2006; Madders & Whittfield 2006; Kuvlesky Jr *et al*. 2007; National Research Council 2007; Arnett *et al*. 2007, Langston & Pullan 2002).

The impact to raptors by wind farm developments in different raptor concentration areas, such as migration routes and wintering raptor areas, to date has largely been unstudied. Therefore the type and extent of effects to raptors, in such areas is unclear. There are some concerns over whether wind farms may cause “barrier effects” where if flight paths are altered the health and fitness of individuals may be impacted. If a wind farm causes a barrier effect and interrupts a traditional raptor migratory pathway, they may need to change their type of flight from energy conserving soaring flight to less energy efficient flapping and/or go to areas of reduced thermal activity causing increased energy expenditure (Hedenström 1993). The energy expenditure cost for powered flapping flight increases steeply as body size increases, which means for eagles and other large raptors and vultures, the implications of reduced flight efficiency are the greatest (Hedenström 1993).

Habitat Change or Loss

The physical area (habitat) modified by the wind farm infrastructure, especially the turbine itself, the adjacent gravel pad (typical of Ontario wind farms), access roads and transmission lines have been implicated as contributing factors to collision risk in California. The modification of habitats from wind farm infrastructure may be beneficial to species at various trophic levels, but also may create risks. The Altamont Pass Wind Resource Area (APWARA) provides the primary example of the compounding effect habitat changes can have. At the APWRA Smallwood and Thelander (2005) found pocket gopher (*Thomomys botta*) burrows to almost always be clustered around turbines. A positive relationship with the abundance of cattle pats around turbines was found. The burrows of pocket gophers are also used by a variety other raptor prey items including small mammals, birds and snakes (Kuvlesky Jr *et al*. 2007; Hunt 2002; Smallwood & Thelander 2005). Burrowing owls (*Athene cunicularia*) are known to use gopher burrows and with those burrows being clustered around turbines the owls are put at risk of collision. From 1998 to 2003 a total of 70 burrowing owl fatalities from turbines were found and Smallwood & Thelander (2007) estimated annual fatalities for burrowing owls as high as 345-1,219 using one estimation method and 99-380 annual fatalities with another method (Smallwood *et al.* 2007).

In the case of Altamont, the grazing of cattle around the turbines has also resulted in several implications that are presumed to contribute to potential collision risk:

- cattle grazing keeps vegetation cover low, which creates habitat preferred by ground squirrels (*Spermophilus beecheyi*) (Morrison 1996);
- dead cattle are often left *in situ,* in which case the carrion than may attract raptors (Morrison 1996);
- insects are attracted to cattle pats, which in turn attracts raptors that will eat the insects (Morrison 1996)

Efforts have been taken to control ground squirrels in half of the APWRA, but in turn have contributed to creating an abundance of carrion from poisoned ground squirrels and desert cottontails (*Sylvilagus auduboni*) which may attract raptors (Smallwood & Thelander 2005). All of these findings show the result of unanticipated effects from wind farms.

New Generation vs. Old Generation Wind Farms

The APWRA, in California, represents an old generation wind facility as the majority of turbines are old generation machines eg. lattice towers, small in size (both height and blade length), rotate at high revolutions per minute, and produce less power per turbine than the larger modern tubular turbines. Turbines are also packed in much more tightly than in new facilities, with the rotors of adjacent machines practically touching in many cases. In North America, the APWRA has become notorious for high levels of raptor mortality and as a result, concerns over the effects wind farms pose to raptors have been raised at many other existing and proposed wind energy facilities. (Smallwood & Thelander 2007; Erickson *et al*. 2001; Orloff & Flannery 1992). By 1998, the APWRA had approximately 5,400 wind turbines and annual estimates of mortality during 1998-2003 of 881-1,300 raptors (434 unadjusted annual fatalities), and an estimated mortality rate of 0.75 raptor fatalities/MW/year (Smallwood & Thelander 2007).

The PESUR and E3 wind energy facilities in Spain, are very similar to the APWRA as they are comprised of both new tubular towers and older style lattice turbines. One wind facility contains 190 turbines, the other 66 turbines. Both the APWARA and the two wind facilities in Spain are located within migration routes for raptors, similar to the Erie Shores Wind Farm. The APWRA may also act as a wintering raptor area as studies have identified high prey abundances within the wind farm which could attract and support raptors to remain in Altamont during winter months (Smallwood & Thelander 2005).

These two wind farms have become the leading examples outside of North America of turbines causing high raptor mortality. The total estimated mortality rate for raptors for the one year study, and at both wind farms combined, was 0.27 raptor fatalities/turbine/year (Barrios & Rodriguez 2004). However, de Lucas *et al*. (2008)

reviewed 9.67 years of mortality monitoring to identify if the mortality trends were maintained over time. Review of the long-term data set on mortality, identified the average annual mortality rate at E3 to be 0.04 raptors/turbine/year and 0.07 raptors/turbine/year at PESUR (de Lucas *et al*. 2008). The long-term data set identified that the high mortality found in early monitoring was not an on-going trend. Griffon vultures (*Gyps fulvus*) and common kestrels (*Falco tinnunculus*) were the species with the highest mortality rates. De Lucas *et al*. (2008) identified over a 9.67 years period that the average griffon vulture mortality rate at E3 was 0.03 raptors/turbine/year and at PESUR was 0.05 raptors/turbine/year. Common kestrel fatalities were only found at PESUR with a mortality estimate of 0.01 raptors/turbine/year (de Lucas *et al*. 2008).

High raptor mortality has also been found at a new generation wind farm located in the Smöla archipelago in Norway, and not sited in a raptor migration route. Impacts to white-tailed sea eagles (*Haliaeetus albicilla*) have taken place at this wind farm in the form of both turbine collisions and displacement of breeding pairs (Follestad *et al*. 2007). Between August 2005 and March 2007 a total of 10 white-tailed sea eagle fatalities were found, with four fatalities occurring in a single week during the 2006 breeding season (Follestad *et al*. 2007).

A few initial studies to attempt to determine whether sensory factors (sight, sound, smell) may play some role in collision fatalities at wind farms have been conducted. Focus to date has been on trying to find mitigation measures that could reduce collision fatalities as a result of possible visual parameters which may influence turbine collisions. Raptors have universal macularity meaning they have a low ratio of receptors to ganglion cells out of the periphery of the retina allowing for good acuity even in peripheral vision (Hodos *et al.* 1991). Raptors also have two foveal regions, allowing for simultaneous frontal vision and the ability to look at the ground for food (Hodos and Erichson 1990). As a result of this ability, Hodos (2001) suggests the hypothesis of collisions occurring from raptors not having the ability to divide attention between hunting and watching the horizon is unlikely. These hypotheses, however, have not be tested to date in the field.

Other hypotheses for causes of collisions include the concept of motion smear. Motion smear occurs when an object moves across the retina with increasing speed, at which point the object than becomes increasingly blurred. When the rotor blades of the turbines turn at a rate of 35 rpm and higher, motion smear becomes more apparent (Hodos 2001). The central and blade tip regions of turbine blades move at the greatest velocity and therefore motion smear is most present in those areas of the turbine blade sweep. The solution to motion smear is to maximize the time between successive stimulations to the same retinal region. Keeping rotation speeds at the blade tips to <35 rpms can act to reduce motion smear, but this can be costly to wind farm operators and they may be reluctant to adopt such a mitigation measure as greater energy is produced at higher wind speeds. The suggested alternative in the literature is to mitigate for collision fatalities by painting the turbine blades (Hodos 2001; McIsaac 2001). By painting different patterns on each of the three turbine blades and at different locations on each blade, the time between retinal stimulations can be tripled (Hodos 2001). Further study on this subject is needed in order further evaluate how different backgrounds to the turbine blades may affect motion smear and the patterns put on the turbine blades (and the colors they are painted). As raptor can perceive the ultra violet (UV) light spectrum, further studies on painting turbine blades with UV paints to see how it may influence reducing motion smear should be conducted. Young *et al*. (2003) conducted a short-term study, monitoring mortality at operation turbines where some turbines in a wind far had blades painted with UV-light reflective paint. This study found no significant differences in mortality at turbines with UV painted blades versus turbines with non-UV painted blades (Young *et al*. 2003).

The north shore of Lake Erie in Ontario acts a major concentration point for autumn raptor migration (Rayner 2004). Annually hundreds of thousands of raptors migrate through Ontario in the autumn and are annually monitored at raptor migration stations such as Hawk Cliff and Holiday Beach (Hawk Cliff Foundation 2004).

The Erie Shores Wind Farm (ESWF) which consists of 66 turbines was made operational in 2006 and presents a unique situation in that it is likely the first new generation wind farm to be sited along a major raptor migration corridor in eastern North America. A recent study by Smallwood & Karas (2009) comparing mortality at old and new turbines (in areas being re-powered) in Altamont, found a 54% decrease in mortality at the new turbines versus old turbines. The study by Smallwood & Karas (2009) therefore suggests that turbine design, dimensions (tower height and blade sweep length, inability for raptors to perch or attempt to nest on towers of new design, and speed of turbine blades), and turbine spacing may be the most important factors that influence what causes turbine collisions.

Are Raptors at Risk from Wind Farms in Ontario?

Concerns have been raised by naturalist and conservation organizations about wind farm effects on birds since some proposed and approved wind farm sites are located in known migratory corridors or staging areas (Nature Canada 2010, Audubon New York 2004).

The raptors which migrate through Ontario during the autumn are typically made up of raptors from the Eastern Arctic, Quebec and Ontario (Rayner 2004; Hawk Cliff Foundation 2004). Raptors are naturally reluctant to cross large bodies of water due to poor thermal development over water, which is not conducive to low energy expenditure types of flight, such as soaring, which are preferred by raptors during migration (Rayner 2004; Hawk Cliff Foundation 2004). Large bodies of water therefore often act as leading lines to many migrating raptors. Leading lines are defined as topographical features with characteristics that cause birds to follow them and include boundaries between suitable and unsuitable habitat, and habitat boundaries such as forest-field edge (Mueller & Berger 1967). The concept of leading lines helps explain why the north shore of Lake Erie concentrates raptors, making it such an important area for raptor migration in eastern North America.

Of the raptors that migrate through Ontario in the autumn, some will find their way to the St. Lawrence River (Rayner 2004). From the north shore of the St. Lawrence raptors find their way southwesterly towards the north shore of Lake Ontario (Rayner 2004). When raptors get to the western end of Lake Ontario they move south-west until they reach the north shore of Lake Erie (Rayner 2004). By the time raptors reach Lake Erie and continue south they are channeled evermore by the narrowing landmass of southwestern Ontario (Rayner 2004). As raptors progress towards Lake Erie they are continually joined by other migrating raptors, causing increasing densities of raptors. During the autumn, raptors are observed near the shoreline because of the thermal updrafts created at this interface which enables them to travel long distances with minimal energy expenditure.

As many as fifteen species of raptors can be seen on a regular basis migrating along the north shore of Lake Erie during autumn (Hawk Cliff Foundation 2004). At Hawk Cliff fifteen species are regularly seen during migration and the 13 year average from 1994-2007 indicates over 60,000 raptors observed per year (Hawk Cliff Foundation 2007). In contrast, in California at the Golden Gate Raptor Observatory (GGRO) (the closest raptor migration station to Altamont) the 1995-2004 average number raptors observations is 29,256 raptors/autumn. In years with low broad-winged hawk movements even, the migration route at Hawk Cliff has at least two times the number of raptors observed than at the GGRO. Broad-winged hawks, however, can cause the number of observations for individual years to be in the hundreds of thousands (for this species alone) at Hawk Cliff, as the entire population will often move through in only a few days (Hawk Cliff Foundation 2007). Broad-winged hawk migration is greatly influenced by winds and other weather conditions on the few days in which they migrate through Ontario, which causes them in some years to be found near the lake and in other years to be far inland. Weather conditions also influence their flight heights and therefore the ability to see their passage, as some days and years they are visible at a few hundred meters above the ground, while on some days of their migration they can be more than 1km above ground. Table 1 shows that the broad-winged hawk (*Buteo platypterus*), turkey vulture (*Cathartes aura*), sharp-shinned hawk (*Accipiter striatus*), red-tailed hawk (*Buteo jamaicensis*) and American kestrel (*Falco sparverius*) are the most common raptors observed at Hawk Cliff (Hawk Cliff Foundation 2007). Figure 1 also shows how species numbers change from month to month, with falcons migrating largely in September and October and most Buteo species passing through later in the migration period, during October and November (Hawk Cliff Foundation 2007). Understanding that individual raptor species and raptor group abundances change as the autumn progresses, is an important consideration for behavioral monitoring studies as failure to recognize such trends can influence what information monitoring will capture.

STUDY OBJECTIVES

The two year monitoring study conducted at the Erie Shores Wind Farm was focused on answering two key questions:

Research Question A: Raptor Mortality Findings

> ***Does high raptor density in a migration route equate to high levels of raptor mortality at an operational wind farm located in an autumn raptor migration route?***

Research Question B: Raptor Behavioral Responses

> ***What is/are the behavioral response(s) by raptors to turbines?***
>
> 1) *Is the collision risk for raptors high or do raptors appear to take deliberate actions to fly around or avoid wind turbines?*
> 2) *How far out from turbines do migrant raptors keep when passing a wind turbine?*
> 3) *What are the flight heights above ground that migrant raptors most frequently fly at to pass wind turbines?*

Chapter 2. Methods

STUDY LOCATION

The Erie Shores Wind Farm stretches east to west across approximately 29km of the north shore of Lake Erie and 2.5km inland from the lakeshore bluffs.

The ESWF is spread across Norfolk County and Elgin County with the wind farm stretching to the east and west of the village of Port Burwell, refer to Map 1 and Map 2. There are 66 turbines in the wind farm in total with 24 (36%) turbines located in the wind farm to the west of Port Burwell and 42 (64%) turbines to the east of Port Burwell.

In the west side of the wind farm a total of 5 (21% of west side turbines) turbines are located <300m from the bluffs (measured from turbine base), a total of 6 (25%) are ≤600m from the bluffs and 18 (54%) turbines are >600m from the bluffs. In the east side of the wind farm a total of 5 (12% of east side turbines) turbines are located <300m from the bluffs, a total of 8 (19%) are ≤600m from the bluffs and therefore 29 (69%) are >600m from the bluffs.

The distance from the turbines to the closest section of the bluff edge ranges from approximately 93m to 2,476m with a mean of approximately 1,054m to bluff edge. The median distance of turbines to the bluff edge is approximately 1,004m with a mode of approximately 961m. There are 10 of 66 (15%) turbines located in the entire wind farm that are within <300m of the bluff edge, and 4 (6%) turbines located >300m to <600m from the bluff edge. There are 52 (79%) turbines located at ≥600m from the bluff edge, with 33 (50%) turbines being sited at >1,000m from the bluff edge.

The average distance between individual wind turbines is 473m. The distance from turbine base to turbine base within the wind farm ranged from approximately 286m to 1,268m, at the farthest.

The Erie Shores Wind Farm is located northeast of Hawk Cliff, one of North America's best locations to observe autumn raptor migration. Hawk Cliff is located approximately 38 km from Port Burwell and has been an active hawk watch site since the 1970's. Between Port Burwell and Hawk Cliff, the bluffs of Lake Erie rise to around 30m high (Hawk Cliff Foundation 2004).

The landscape around the Erie Shores Wind Farm is a mosaic of active agriculture crop fields including soybean, asparagus, and corn. Pasture, hayfields and old fields are virtually non-existent in the area of the wind farm due to the sandy soils of the area. Woodlands within the study area were typically small and isolated and included the occasional wooded ravine with streams that flow into Lake Erie. Apart from the bluffs, the topography of the wind farm area is flat. The flat topography of this area is a major difference from the Altamont and Tarifa, Spain wind farms where large hills or mountains dominate the landscape (Barrios & Rodriguez 2004).

The eastern most turbine was located at 17N, Easting: 538041; Northing: 4715754. The western most turbine was located at 17N, Easting: 504136; Northing: 4723932.

The Erie Shores Wind Farm is a 99 MW facility and comprises of 66 General Electric 1.5 sle turbines, which have a 1.5 MW capacity per unit.

The blade sweep height for the turbines was 41.5m to 118.5m above ground.. The radius of each turbine blade from the center of the hub was 38.5m, see Illustration 1.

The ground cover at the base of the turbines studied was easy to search with ground cover generally being low. The search ability at turbines generally improved as the autumn progressed due to crop leaf dieback and crop removal. The ground cover at the twelve turbines I monitored is identified in Table 2. Ground cover around the turbines included soybean, corn, grass and weeds, mini pumpkins, squash, asparagus, deciduous woodlot edge and the turbines gravel pad and roadways. The vegetation cover under the turbines at ESWF was not particularly dense during the autumn (with the exception of corn), compared to other wind farm locations in Ontario such as Wolfe Island where grasses under the turbines can be 1m tall and extremely dense.

The Erie Shores Wind Farm pre-dates the current rules and guidelines outlined in the Ontario Green Energy Act (Ministry of Energy 2009). As a result of this, the placement of turbines within the wind farm area was much less stringent than what is currently required through the Green Energy Act. Some turbines at Erie Shores are therefore placed closer to the lakeshore bluff edge and woodlots than what is now allowed because of the very specific set-back distances from various natural features and human structures, which are set out in the Green Energy Act (Ministry of Energy 2009).

STUDY DESIGN AND TECHNIQUES

Permission to access the wind turbines and gather data for this study was granted by AIM PowerGen Corporation in September 2006 and 2007 prior to conducting any field research.

Of the 66 turbines, 12 were selected to answer my research questions, based on the resources available to complete the study. Obtaining highly detailed observations at a few locations was deemed of greater value than collecting a little information at numerous locations. The turbines used in the study covered a good cross-section of the turbines in the wind farm as a result of using the following selection criteria:

1) 8 sites located within 300m of the edge of the bluffs, and 4 sites located between ≥600m and 2,476m (the farthest inland turbine) inland. Turbines near the bluffs and far away from the bluffs were examined so that it could be determined whether turbine location, in relation to the bluff edge, influences mortality. The heaviest flights of raptors occur right along the lakeshore. If high mortality were to occur, most likely it would be at the turbines closest to the shoreline, which is why I selected a disproportionate number of turbines in this distance zone.

2) 6 sites in the eastern section of the wind facility, and 6 sites in the western section to answer whether raptor movement was observed through the entire wind farm to indicate that the wind farm was not causing barrier effects; As raptors enter the site from the east and proceed westward I also wanted to be able to identify whether raptors were more vulnerable at either end of the wind farm (in the east, because the turbines represent something new in the landscape; in the west, maybe because they've let their guard down)

3) Good visibility of the horizon, to observe daily bird movements (Osborn *et al*. 1998);

4) Turbines with access roads that allow for good vantage points for observers to estimate flight height and distance from the turbine; and

5) Proximity of turbine to woodlots, so it would be possible to see whether raptor flight heights, and distances raptors passed turbines varied at those turbines

Twelve turbines were selected from the turbines that met the criteria outlined above. If a turbine that was selected was part of a pair or group of turbines which also met the selection criteria, than they also became one of the twelve turbines monitored. Of the twelve turbines that were used in the study, eight were between 93m & 264m inland from turbine base to the bluff edge, see Table 2. The eight bluff edge turbines used in my study represented 80% of all turbines in the wind farm at <300m from the bluffs and 57% (8 of 14) of turbines <600m from the bluffs. Four of the turbines used in the study were classified as being located inland because they were >600m inland, ranging between approximately 659m and 1,306m inland from the bluffs. The spacing between the twelve turbines monitored and the next closest turbine ranged from 383m to 821m. This is a significant difference between the ESWF and other wind farms with high raptor mortality such as those in California and Tairifa, Spain where distances between turbine blades is only in the tens of meters (Barrios & Rodriguez 2004).

Mortality Searches

James (2008) completed mortality monitoring at Erie Shores from spring 2006 to autumn 2007, where he searched all of the turbines in the wind farm at regular intervals. The amount of mortality search effort by both James and Dance during 2006 and 2007 is shown in Table 3. During autumn 2006 and 2007, searches covered the prime raptor migration period, see Table 3. As Table 3 notes, James conducted additional searches at some of the turbines near the lakeshore following days of heavy migration; as it was assumed near the lakeshore would be where the greatest concentration of all bird movement (raptor and non-raptor movement) would take place. This approach was taken as it was anticipated that this is when the greatest likelihood of fatalities would occur, due to increased abundances of raptors passing through the wind farm. Many turbines were also visited multiple times by James during a week in order to put out or check scavenger removal birds, and to conduct late afternoon and evening waterfowl surveys. While systematic searches were not conducted during these times it was also possible to find birds during these other activities.

Mortality searches at all 12 turbines used to gather behavioral observations of migrant raptors were conducted to augment the mortality searches conducted by Ross James at regular scheduled intervals. My mortality searches were conducted after behavioral observation monitoring ended for the day. The turbines used for behavioral observations on any given day were searched that same day, and would often include any other turbines in the same turbine row. As Table 3 indicates, mortality search frequency was increased in 2007 from that in 2006. A regular search effort was therefore directed at the twelve turbines used in my study between the searches by James and myself.

An intensive search radius around the turbine of 40m, was selected based on the resources available to conduct the study. From 2006 to 2007 both James and Dance increased the amount of time spent searching, with James doubling his search time, see Table 3. The amount of search effort was calculated as total person/minutes of searching and was calculated as the total time each individual person spent searching eg. 2 people searching for 10 minutes = 20 total person minutes.

James' (2008) search method during 2006 and 2007 involved walking back and forth in parallel transects 4-6m apart in grassy fields and 6-10m apart in crop fields and covered a radius of 40m out from the turbine. A 40m search radius was deemed appropriate as raptors are large birds which are likely to fall straight down after a collision due to their weight. The recommended 50m search radius of Environment Canada is for all birds and bats, which due to their small size could be thrown by turbine blades or blown by strong winds. Also due to the large size and long-term persistence of raptor carcasses it was believed that carcasses just outside of the search area would likely be visible to searchers when they were in the outer range of the search radius. My mortality surveys involved walking expanding circles out from the turbine base 5-6m apart, until the searcher reached the edge of the turbine blade tips where 4-5m out from the turbine blade tips could be seen. A 40m radius was searched in total, see Illustration 2. The details recorded on fatalities were based on the Environment Canada (2006) guidance document "Recommended Protocols for Monitoring Impacts of Wind Turbines on Birds".

In order to validate mortality survey findings, searcher efficiency trials and scavenger removal studies were completed (Barrios & Rodriguez 2004; Drewitt & Langston 2006; Smallwood & Thelander 2005; Arnett 2006; National Academies Press 2007).

Searcher Efficiency Trials

Searcher efficiency trials involved placing 0-4 bird carcasses under a turbine in random locations within the regular 40m search area, with all ground cover types being covered. During searcher efficiency trials searchers spent their regular amount of effort conducting their mortality searches (ie.10-15min). Birds of American robin (*Turdus migratorius*) size (38.7% of birds placed out) to that of birds up to red-tailed hawk size (61.3% of birds placed out) were used. As most raptors are considerably larger than American robin's it is likely that the determined searcher efficiency rates are 'conservative' estimates. Eight different trials were completed for each of the three searchers, with a total of 80 birds thrown out during individual searcher efficiency trials.

Searcher efficiency trials for pairs of searchers were also conducted because there were occasions where mortality searches involved two individuals searching the turbine simultaneously. Therefore to assess whether or not two searchers markedly increased searcher efficiency, pairs of searchers were tested during the searcher efficiency trials. Searcher efficiency trials were conducted four times for each pair of searchers in 2007, with 25 birds being thrown out during trials for pairs of searchers.

James' (2008) searcher efficiency trials used birds that were thrush size or smaller. The searcher efficiency trials were conducted at two turbines with grass cover where up to 10 birds were placed out, as turbines with this ground cover type were far apart from each other and often were single turbines. Then searches were done at pairs of turbines with varying types of ground cover, with 0-2 birds thrown out under the turbines.

Scavenger Removal Studies

Scavenger removal studies were conducted in order to identify if and how quickly birds of all sizes were removed or scavenged upon. During both years, birds were thrown out weekly around the turbines from late August to the end of October (James 2008). In 2006, the birds were checked weekly during the regular searches of the turbines, with 2 to 20 birds thrown out weekly (pers. comm. James 2010). During 2007 six birds were thrown out on the Monday of each week, one hour before sunset (James 2008). In 2007, the birds were checked for one day removal rates (Tuesday), than for midweek removal rate (Friday) and then for the one week removal rate (James 2008). In total 64 birds were used in 2007 to determine the scavenger removal rate (James 2008).

Environment Canada (EC) Mortality Rate Calculation

The EC mortality rate calculation to determine the amount of autumn mortality at Erie Shores is shown below in equation 1 with equations 2, 3, and 4 used to calculate the values which are put into equation 1. I used a range of searcher efficiency values ranging from the lowest to the highest and that of the average of all observers at my sub-set of twelve turbines (with the average being the same as James searcher efficiency for small to medium birds).

Equation 1) *Autumn Mortality Rate Calculation*

$$C = c / (Se * Sc * Ps)$$

C = the corrected number of bird or bat fatalities
c = the number of carcasses found
Se = the proportion of carcasses expected to be found by searchers (searcher efficiency)
Sc = the proportion of carcasses not removed by scavengers over the search period
Ps = the percent of the area searched (measured as a % of a 40 m radius around the turbine base

Equation 2) *Searcher Efficiency Calculation (Se)*

$$Se = \underbrace{(\text{Searcher Efficiency})*(\text{Proportion of Area Searched})}_{\text{Data set 1(Dance)}} + \underbrace{(\text{Searcher Efficiency})*(\text{Proportion of Area Searched})}_{\text{Data Set 2 (James)}}$$

Equation 3) *Scavenger Removal Rate Calculation (Sc)*

$$Sc = \frac{\text{Number of Scavenger Removal Trial Carcasses Remaining over the Study Period}}{\text{Number of Carcasses Placed out for Scavenger Removal Trials}}$$

Equation 4) *Percent of Area Searched Calculation (Ps)*

$$Ps = \frac{\textbf{Total Area (m}^2\textbf{) of ``X'' Search Radius Covered During Mortality Searches}}{\textbf{Area (m}^2\textbf{) for a 40m Search Radius out from a Turbine}}$$

Behavioral Observations

Behavioral monitoring was conducted during peak raptor migration during 2006 and 2007. In 2006 monitoring began in mid September and continued until the beginning of December to determine the extent of raptor migration at the study location. Monitoring in 2007 began at the beginning of September and ended at the end of November based on 2006 data.

The frequency at which behavioral monitoring was conducted varied from week to week due to weather conditions for migration. The dates of monitoring were focused especially on days with weather conditions which were known to be favorable for raptor migration and times of the migration season that would capture periods of peak movement for specific species. As there are only so many days during the migration period which are ideal for large migration movements, monitoring was also conducted on days with conditions where at least some raptor migration would take place. Behavioral information under a variety of weather conditions, which might influence how raptors pass wind turbines, was than able to be collected.

Average dates of raptor movements at Hawk Cliff for each species of the raptor observed at Erie Shores, is shown in Figures 1 to 4, based on 2002 to 2008 data. A peak movement chart, however, was not available from Hawk Cliff for northern harrier

(*Circus cyaneus*). Harrier migration begins in late August with it quickly increasing until mid-September (on average peaking on September 15-21) based on 2002-2007 data (Hawk Cliff 2009). This information was used to ensure the survey period would cover the migration time for the majority of raptor species passing through ESWF.

Upon arrival at an observation station the weather conditions were recorded. Temperature and wind speed were calculated using a Kestrel 3000, and other information including start time, cloud cover (as a percent), precipitation and precipitation in the previous 24 hour period were recorded at the beginning of the observation period (Holiday Beach Migration Observatory 2002). In 2006, changes to weather conditions during the observation period were recorded when they took place. During 2007 wind direction, wind speed, temperature, percent cloud cover, and precipitation were recorded hourly (Maransky *et al*. 1997).

Monitoring for raptor behavior around operational turbines began between 0800 hrs and 0900 hrs based on preliminary site visits and literature review (Woltmann & Cimprich 2003; Maransky *et al*. 1997, Martin, 2007).

Behavioral observations involved observers positioning themselves 90-150m from a turbine, and scanning the sky with binoculars or spotting scope. When a raptor was observed the species, distance from turbine, flight height, age, sex, direction of the birds movement, and details of the birds flight path and/or behavior, were recorded using a Sony ICD-P320 digital voice recorder.

The distance of a raptor from the turbine was recorded as a range of distance (in meters) out from the turbine base. The wind turbines themselves were used as reference to estimate the distance away from the turbine, since they have known dimensions

(Hoover & Morrison 2005). Distances from the turbine to other key features such as to bluff edge or hedgerows were measured using a 50m measuring tape, to improve accuracy of distance estimates.

Flight height of raptors above ground was assigned to one of three categories based on the dimensions of the wind turbines: under blade sweep height = 0-40m; blade sweep height = >40-118.5m, and above blade sweep height = >118.5m.

It was assumed that that the zone of risk was 41.5m to 118.5m above ground and 0-40m out from the turbine.

On dates where there was only one observer gathering data, the following approach was taken. An observer would remain at one monitoring station for the entire day of monitoring unless the following circumstances arose:

a) If monitoring a shoreline turbine and part way through the day raptor observations dropped off significantly (<4 or 5 raptors/hr), but significant raptor movement was observed inland (eg. due to winds shifting direction etc.) then the observer would move inland in order to continue to gather as many observations of raptors passing turbines as possible. The same approach applied to if one was initially at an inland turbine, and raptor movement shifted to the bluffs.

b) If raptor observations dropped off significantly (<4 or 5 raptors/hr) and limited raptor movement was occurring for the day the observer could also go to the opposite side of the wind farm to identify if limited migration was occurring there as well.

On days in which there were two or more observers the monitoring approach taken was that one observer would gather observations at a turbine(s) located inland and the other would collect data at a lakeshore turbine(s). This approach also applied for data collection at groups of turbines, where both observers would gather data at the same group of turbines but one observer would be located at the turbine(s) near the lakeshore and one observer would situate themselves at the farther inland turbine(s) of the group. On some dates with heavy raptor migration along the shoreline and there were two observers, each would situate themselves at a different lakeshore turbine which enabled for the most observations to be collected of raptors passing turbines.

Mapping from AIM PowerGen was used to determine distance measurements within the wind farm and was loaded into an ArcMap GIS software program. The distance measurement tool was selected from the tools menu and the map scale was set at 1:5000. Using the measurement tool, distances from the one turbine to the nearest turbine and closest distance of each turbine to the bluff edge were determined and recorded in meters.

Chapter 3. RESULTS

RESULT SUMMARY

Observations were made on 22 days from September 18th to December 4th in 2006 (refer to Table 4), at the subset of 12 turbines monitored. In 2007, observations were made on 43 days from September 5 to November 28th (refer to Table 5), at the subset of 12 turbines monitored. Below are the main findings categorized as mortality or behavioral findings.

Raptor Mortality

- 19,266 person/minutes were spent conducting mortality searches by James and Dance combined
- 2 raptor fatalities found in 2006; 2 raptor fatalities found in 2007
- All four raptor fatalities were of different raptor species
- Mortality was not concentrated at specific turbines, and was distributed equally at inland and bluff edge turbines and turbines in the east and west portions of the wind farm
- The mortality rate for ESWF was found to range from 0.028 to 0.049 raptors/MW/autumn

Behavioral Observations

- 368 person/hrs and 19 minutes were spent conducting behavioral observations
- A total of 6,960 observations were recorded of raptors up to 2km away
- 5,579 raptors were observed within 250m of turbines in autumn 2006 and 2007
- Turkey vultures, sharp-shinned hawk, and red-tailed hawk were the species observed in decreasing order of abundance.
- 9% (n= 159) of raptors were observed flying at blade sweep height within 250m
- 2.92% (of 5,443 observations) of raptors observed were in the actual risk zone (0-40m out from a turbine and at 41.5-118.5m above ground)
- 11.3% of all raptors passed within 0-40m out from turbines, regardless of flight height (Figure 7)
- 27% of all raptors were observed passing turbines at blade sweep height, regardless of their distance out from the turbine base (Figure 8)

RAPTOR MORTALITY

Effort

Analysis of mortality search effort at ESWF by James and Dance in autumn 2006 and 2007 combined identified 19,266 person/minutes of searching. As indicated in Table 3, mortality searches in 2006 lasted 15 minutes and effort was increased in 2007 with searches ranging from 25 to 45 minutes depending on site conditions (James 2008). The dates and the turbines searched for mortality searches on a given day by James are shown in Table 6 and Table 7, respectively.

A total of 241 individual turbine searches were conducted over the study period at the twelve turbines researched by Dance, with a total of 3,475 person/minutes spent conducting the turbine searches. Nearly 4 times the search effort was spent in 2007 than in 2006, Table 3. During 2006, the average time of searches was approximately 11.2 minutes with a mode of 10 minutes. In 2007, the average search time increased to 16 minutes with a mode of 20 minutes. The 2006 and 2007 mortality search dates by Dance are shown in Table 8.

Collision Fatalities Found

Four raptor fatalities were found over the two year study, with two individual raptors being found each year. One fatality per year was found at the subset of twelve turbines.

2006 Fatalities

On September 26, 2006 a fresh immature sharp-shinned hawk (*Accipiter striatus*) fatality was found 30-35m out from the turbine with a broken sternum and missing tail and pelvis. The turbine that caused this fatality was located in the east end of the wind farm, 93m from the bluff edge and approximately 463m away from the closest turbine, see Illustration 3. James (2008) found a turkey vulture (*Cathartes aura)* on October 12, 2006 at a turbine along the northeastern edge of the wind farm (approximately 2,150m from the bluff edge). The turkey vulture was 23m away from the turbine, had a split sternum, and was in an advanced state of decomposition where only bones and feathers remained (James 2007).

2007 Raptor Fatalities

An immature red-tailed hawk (*Buteo jamaicensis*) was found on November 29, 2007 at a turbine in the west end of the wind farm, situated 264m inland, and 40m north of a woodlot situated between the turbine and the cliff edge. The red-tailed hawk fatality was found approximately 70m southwest of the turbine and approximately 30m into the north edge of the woodlot, see Illustration 4. The red-tailed hawk had damage to its left wing and sternum. An adult Cooper's hawk (*Accipiter cooperii*) was found on October 3, 2007 in the eastern half of the wind farm, along the northern edge of the wind farm, approximately 1,960 from bluff edge. The Cooper's hawk was found 0.5m from the base of the turbine, with only a visible injury to its right eye.

Non-raptor fatalities Found

During the 2006 autumn mortality searches a total of four non-raptor fatalities were found, two passerines and two bats (at the sub-set of twelve turbines studied). During the mortality searches conducted in 2007 a total of five passerines and fourteen bats were found, totaling nineteen non-raptor fatalities found at the sub-set of twelve turbines studied).

Mortality Rate Calculation, Environment Canada Method

There were two raptor fatalities found in 2006 and two in 2007, as a result the mortality rates I calculated for the wind farm were assumed to be an appropriate reflection of mortality for both years, as scavenger removal data was pooled for 2006 & 2007 and searcher efficiency was evaluated only in 2007 and was assumed to be reflective of searcher efficiency during both monitoring years.

Searcher Efficiency

Individual searcher efficiency values were calculated to be 75%, 77% and 86% with an average of all three searchers combined at 79% (equal to James' searcher efficiency for birds of all sizes), see Figure 4. The lowest individual searcher efficiency, the highest searcher efficiency and the average of all searchers were used to determine three **Se** values. James' searcher efficiency for small to medium birds (which is a conservative estimate of his efficiency as it would likely be greater for larger birds) was used. The proportion of turbines searched by James and myself were calculated in Figure 4.

Scavenger Removal (Sc)

The scavenger removal rate for large birds at ESWF was 11% and therefore the proportion of carcasses not removed over the search period was 0.89 (89%), see Figure 5. Details on the dates scavenger removal trial were conducted, and the number of birds placed out are shown in Table 9. The proportion of birds put out per month is also shown to indicate that the scavenger removal trials were conducted during peak raptor migration.

Proportion of Area Searched (Ps)

At the subset of twelve turbines I searched, 100% of the area was always searched, despite the ground cover type. To provide a more conservative estimate, recognizing how ground cover varied throughout the wind farm and through discussion with James, I assumed an appropriate minimum of area searched per turbines to be 60%. I therefore calculated the autumn mortality rate for the wind farm using PS values of 100% and 60% to determine a range of mortality for the wind farm.

Autumn Mortality Rate

The mortality rate for the wind farm ranged from 0.028 to 0.049 raptor fatalities/MW/autumn, see Figure 5. The mortality rate of 0.049 was based on a 40% of the area under all of the turbines not being searched.

BEHAVIORAL OBSERVATIONS

Effort

A total of 6,960 observations were recorded of raptors up to 2km away in which data on flight height and/or distance were recorded. A total of 5,579 raptor observations (where height and/or distance data was recorded) were made within 250m of turbines.

A total of 368 person/hrs and 19 minutes of behavioral observations were made, over 64 days, during the study.

Monitoring in 2006 identified minimal to no raptor migration occurring from mid-November to the beginning of December. Monitoring therefore was ended in 2007 prior to December, see Table 5.

Behavioral monitoring was conducted on 1-2 days per week during 2006, and monitoring effort in 2007 was increased to as many as 4 days of observation per week.

Start times at Erie Shores prior to 0800 hrs did not result in the identification of any significant raptor movements in the early morning, therefore monitoring typically began after 0800 hrs.

The number of observation dates doubled in 2007, and the number of hours spent observing reflects this with more than two times the number of hours of observation spent in 2007 than in 2006.

Raptor Species Observed at Erie Shores

Fifteen species of raptors were observed passing through the wind farm as shown in Table 1. Turkey vulture was the most abundant species observed, followed by sharp-shinned hawk, and red-tailed hawk, with Cooper's hawk and American kestrel being of approximately equal abundance. Broad-winged hawks are one of the most abundant species observed at nearby Hawk Cliff, but only 10 were observed at Erie Shores. No broad-winged hawks were found dead under any turbines, so even if their movements were missed the lack of any fatalities suggests there was low collision risk for the species at this site during the study (conditions might be different in other years i.e., flights were low, or conditions might be different at other sites along the L. Erie shore).

Risk Zone Observations

No evidence was found to suggest that the turbine pillar is a potential cause of fatality.

Analysis of only blade sweep height observations within 250m of turbines identified 9% (n= 159) of the raptors observed passed within 0-40m of turbines.

Out of all 5,443 observations where both flight height and distance from turbine were recorded within 250m of a turbine, 2.92% (n=159) of all observations were of raptors in the actual risk zone.

Raptors observed within the risk zone fit into one of six situations, see Table 10. As Table 10 indicates 73% (n=116) of the raptors that passed turbines within the risk zone did so when conditions resulted in a smaller area of risk. In these situations the collision risk was reduced because the raptor:

- passed the turbine parallel with the orientation of the turbine blades (43%; n=69);
- passed the turbine when the turbine blades orientation was partially perpendicular to the path of the bird (24%; n=38); or
- the turbine was not operational (6%; n=9).

Most noteworthy is the 13% (n=20) of raptors observed in the risk zone where near collision events occurred, but the raptors flight abilities allowed for last second avoidance.

Only 0.14% (9 of 6,631 observations) of all raptors observed over the study period passed directly through the blade sweep area (moving perpendicular to the turbine blades) and survived (based on no fatalities found afterwards during mortality searches or were visually seen continuing on past the turbine).

Distance from Turbine

I analyzed 5,579 raptor observations within a 250m radius of all of the turbines (regardless of the raptors flight height, direction around the turbine the raptor passed, and the location of the turbine in relation to the lakeshore).

For all observations within 250m of turbines, 617 raptors were observed passing within 0-40m of turbines regardless of their flight height. For raptors observed passing within 0-40m of a turbine, 26% (n=159) were observed at blade sweep height, see Figure 6.

Analysis of distance data out from turbines that raptors passed, at 40m intervals, identified 73% of raptors observed (5,579 observations) passed turbines between >40-160m, shown in Figure 7. Raptors that passed turbines within 0-40m, comprised 11.3% of all raptors with distance from turbine data, regardless of their flight height.

Flight Height

A total of 6,631 raptor observations were made in which flight height data was recorded. As shown in Figure 8, 27% (n=1804) of raptors passed turbines at blade sweep height, irrespective of distance out from the turbine and location of the turbine in relation to the bluff edge.

Raptor Movement Patterns

During the first two years of operation of the wind farm raptors were continuing to migrate through the wind farm, with over 6,960 raptors being observed. Raptors were observed passing all twelve of the turbines used in the study, which includes turbines near the bluff edge and turbines 1,306m inland from the bluffs.

Chapter 4. DISCUSSION

DISCUSSION

Two main research questions were examined through this research study and are discussed as Question A: Raptor Mortality Findings, and Question B: Raptor Behavioral Responses.

Research Question A: Raptor Mortality Findings

> **Does high raptor density in a migration route equate to high levels of raptor mortality at an operational wind farm located in an autumn raptor migration route?**

The Relationship between Raptor Abundance and Mortality

It has been traditionally assumed that high bird abundance around turbines is likely to equate to a high potential for collision mortality. The estimated autumn mortality rate of 0.028 to 0.049 raptors/MW/autumn at Erie Shores is low compared to the relative abundance of raptors observed. The findings at the ESWF contrast with both the APWRA and the mortality findings at the PESUR and E3 wind farms in Spain, where high abundances of raptors are also found (Barrios & Rodriguez 2004; de Lucas *et al.* 2008). My findings appear to be in line with the findings of de Lucas *et al.* (2008) that suggest that abundance in terms of sheer numbers of individuals is not necessarily the only or primary driver of mortality. If that is the case, then other factors may be influencing mortality at some level.

Species composition may be a possible factor influencing mortality. At Erie Shores the raptor mortalities found comprised of the four most abundant species observed migrating thorough the wind farm. However, no multiple fatalities of any one raptor species were found during autumn migration. Further study and larger mortality datasets are needed, however, in order to better understand how species abundance influences the number of fatalities and species of raptors found. It is also important to consider if species abundance influences mortality simply because there may be more individuals in that population, which could be injured or unhealthy, making them susceptible to becoming a collision fatality.

Certain flight behaviors have also been considered to be an influence in raptor fatalities in California (Hoover & Morrison 2005). Studies of red-tailed hawk flight behavior at the Altamont Pass Wind Resource Area, suggest some turbine collisions to be associated with "kiting" flight behavior which is related to slope-characteristics and high wind speeds (Hoover & Morrison 2005). Kiting is a relatively motionless, flapless flight of a bird in a deflection updraft (Hoover & Morrison 2005). The landscape of the north shore of Lake Erie is flat with scattered small woodlots and hedgerows, while in contrast the APWRA contains slope elevations as high as 347m (Hoover & Morrison 2005). The flat agricultural landscape at ESWF does not make "kiting" a regular type of flight used and may explain why red-tailed hawks during migration were not found to make up a higher proportion of fatalities than any other raptor species. The kiting flight behavior adopted by raptors in the APWRA due to the difference in topographic features, may contribute to the difference between the APWRA and Erie Shores.

Mortality at Erie Shores and Other Facilities Outside of California

The estimated raptor mortality rate for Erie Shores was 0.028 to 0.049 raptors/MW/autumn and is at the low end of mortality at modern generation wind facilities which have experienced some raptor mortality, see Table 11. Based on a recent summary of raptor mortality at twenty-eight wind facilities by the NWCC (2010), the

ESWF would rank as having the 7th lowest mortality of twenty-nine facilities if added to the list of wind farms analyzed in this study.

ESWF fits in the low range of estimated mortality rates at wind farms outside of California, where mortality is found to range from 0.01 to 0.09 raptor fatalities/MW/year (National Research Council 2007). Despite the high abundance of raptors during the autumn at ESWF, its estimated mortality rate is comparable to facilities like Buffalo Ridge Phase I Wind Farm, Stateline Wind Farm, Nine Canyon Wind Farm, Foote Creek Rim Phase I, and Foote Creek Rim Phase II, and Melancthon Phase I that are not in significant migration routes (National Research Council 2007; Stantec 2007).

Raptor mortality at the Melancthon Wind Farm during 2006 and 2007 for example was estimated at 0.013 and 0.047 raptor fatalities/MW/year (based solely on red-tailed hawk fatalities over Spring and Autumn) (Stantec 2007). This wind farm is located centrally in Ontario near the town of Shelburne, which is approximately 209 km from Port Burwell. The Melancthon Wind Farm is approximately 58 km from Georgian Bay, the nearest large water body and is not located in a known autumn migration route, yet the 2007 mortality rate estimate is comparable to that of ESWF.

In contrast to my findings at the ESWF, twenty-two raptor fatalities have been found at the Wolfe Island Wind Farm (WIWF) from July 2009 to June 2010 (Stantec 2010). The mortality rate for the WIWF for the first year of operation was estimated at 0.12 raptors/MW/year (Stantec 2010). Fatalities at the WIWF comprised of one osprey (*Pandion haliaetus*), one northern harrier (*Circus cyaneus*), seven turkey vultures, ten red-tailed hawks, two American kestrel's, and one merlin (*Falco columarious*). The WIWF comprises of eighty-six, 2.3MW wind turbines sited in the west half of Wolfe

Island located in St. Lawrence River just south of Kingston, ON. Wolfe Island is a known wintering raptor and spring staging area for raptors. In contrast to ESWF where raptors were observed quickly migrating through the wind farm Wolfe Island may represent an area where raptors spend more extensive periods of time, due to the presence of high quality foraging habitat. Wolfe Island contains large areas of old field and pasture lands which supports high populations of rodents and small mammals. The situation at Wolfe Island may be similar to what has been found at Altamont, where cattle were found to cluster around the turbines for shade causing concentrations of cow patties which attracts rodents and insects (Smallwood *et al.* 2007). The insects and rodents which are attracted to the area under the turbines may then draw hunting raptors in dangerously close to rotating turbine blades. These factors may be why Wolfe Island has an unadjusted annual raptor mortality that is 11x that of Erie Shores (22 vs. 2). The unadjusted mortality findings of 22 raptors at the WIWF may even be an under estimate of mortality due to the tall (up to 1m tall), dense grass and other vegetation cover under many of the turbines. This is vastly different from Erie Shores where shorter less dense agricultural crops comprised the typical vegetation cover under the turbines with fatalities being much harder to miss under such circumstances. Also, similar to Altamont, the majority of fatalities (45% of fatalities) at the WIWF were red-tailed hawks.

In October of 2010, the Ontario Ministry of Natural Resources adopted the use of mortality thresholds to identify negative effects resulting from the operational wind farms and to indicate when mitigation measures may be required. The current mortality thresholds for raptors are as follows (MNR 2010):

- 18 birds/turbine/year at individual turbines or turbine groups;

- 0.2 raptors/turbine/year across a wind power project;
- 0.1 raptors/turbine/year (raptors of provincial conservation concern) across a wind power project; or
- 2 raptors/wind power project (of <10 turbines)

The first two raptor mortality thresholds are based raptor mortality rate estimates per turbine per year at the entire wind farm project. It is therefore important to recognize that the actual number of raptor fatalities that are needed to reach these thresholds varies on the size of the project ie. at a 25 turbine project five raptor fatalities would cause the threshold to be reached but at a 250 turbine facility 50 individuals would cause the threshold to be reached. The raptor mortality thresholds, fail to account for situations where specific turbines or turbine groups may cause all or the majority of raptor fatalities. As a result no form of mitigation is required at those turbines as long as long as <18 birds are found killed at a specific turbine or group of turbines (this does not account for birds not found). The appropriateness of basing the threshold values on the highest reported amount of raptor mortality outside of California is somewhat questionable as it indicates anything below that has minimal impacts to raptors (also the highest mortality value used may be well above that of the typical wind farm). It is unclear why the average amount of raptor fatalities/turbine/year was not chosen as the threshold value, as raptor mortality above that would indicate above normal levels of raptor mortality. The current threshold approach by OMNR, in essence requires a wind farm to have greater raptor mortality than the worst case levels known outside of California in order for mitigation to be required.

Mortality at ESWF compared to Altamont and Tairifa, Spain

Raptor fatalities found at the 'older' generation wind farms in California including the APWRA, Montezuma Hills, and Tehachapi Pass show by far the greatest raptor mortality for wind farms in North America, with mortality rates ranging from around 0.25-1.0 raptors/MW/year (National Research Council 2007). Mortality data from 1998-2002 resulted in an unadjusted estimate of 0.75 raptor fatalities/MW/year and an adjusted estimate of 1.94 raptor fatalities/MW/year at the APWRA (15 to 72 times greater than estimates for ESWF) (Smallwood & Thelander 2007a). During Smallwood & Thelander's (2007a) study 434 raptor fatalities were found and when adjusted for scavenger removal and searcher efficiency, 1,127 raptor fatalities were estimated per year.

Species Composition of Collision Fatalities

The mortality findings at ESWF exhibit a different species composition for raptor fatalities compared to the APWRA in California where the red-tailed hawk, golden eagle and American kestrel exhibit the greatest mortality (Smallwood & Thelander 2007). All three of these species migrate through the ESWF and only a single red-tailed hawk fatality was found during autumn monitoring. Data from nearby Hawk cliff data indicates as many as of 4,874 red-tailed hawks, 113 golden eagles, and 3,069 American kestrels are observed annually (Hawk Cliff 2007b, Hawk Cliff 2007c, Hawk Cliff 2007d). Despite the high numbers of some of these species migrating through the ESWF the limited amount of raptor fatalities found suggests there is something different about the ESWF situation that is influencing the limited amount of mortality of these species.

Mortality in the larger raptors like golden eagles and red-tailed hawks at Altamont may be the result of a combination of factors including:

- Presence of old generation turbines, which have high revolutions per minute, and provision of perching and nesting habitat in a landscape in which both are limited
- Turbine layout: turbines are close together and in long turbine rows, and the use of wind walls etc. which may act as barriers to movement
- Sloped terrain: The ridgelines and large hills where turbines are sited may influence the flight strategies raptors use ie. increased "Kiting"
- Altamont may act as more of a staging area for raptors and with high prey abundances in the wind farm may cause more raptors to be hunting in the wind farm compared to at Erie Shores. Individuals may therefore be remaining in the wind farm for more extended periods of time compared to raptors at ESWF that appear to migrate quickly through the wind farm. This may also be the case at the Wolfe Island Wind Farm (WIWF) in Ontario, which is in a raptor wintering area and spring raptor staging area. Wolfe Island has extensive old fields and pastures on the island, which are habitats known to support high rodent populations (OMNR 2000). Studies are needed to determine whether exposure time to operating turbines due to remaining in the wind farm to hunt is a contributing factor to mortality. Many of the wintering raptors at Wolfe Island are there for almost half a year. So not only are raptors plentiful but they're hanging around for a long while, which may increase an individual raptors likelihood of

colliding with a turbine blade. This could help explain why wind farms in raptor staging areas like the Wolfe Island Wind Farm have greater mortality compared to a site located in a migration route dominated by agricultural crops, such as the ESWF.

Research Question B: Raptor Behavioral Responses

What is/are the behavioral response(s) by raptors to turbines?

1) *Is the collision risk for raptors high or do raptors appear to take deliberate actions to fly around or avoid wind turbines?*
2) *How far out from turbines do migrant raptors keep when passing a wind turbine?*
3) *What are the flight heights above ground that migrant raptors most frequently fly at to pass wind turbines?*

1) Is the collision risk for raptors high or do raptors appear to take deliberate actions to fly around or avoid wind turbines?

Near Collision Events

At ESWF avoidance was taken by most raptors at a matter of tens of meters out from the turbine blades, which keeps them out of the risk zone of height and distance out from the turbine. During behavioral observations it was observed on some occasions that raptors would adjust their flight trajectory when approaching a turbine. Sometimes this would occur at over 500m from the turbine, so that they would pass the turbine at a distance outside of the blade sweep. In other instances some raptors even entered the risk zone where they would than take avoidance at the last second to avoid a rotating turbine blade.

Of the 20 observations of near collisions, frequently it was the flight abilities of the raptors which enabled them to avoid near collision with the rotating turbine blades. My observations of near fatalities, but without any actual fatalities of those raptors, identifies that raptors within the risk zone or that even fly through the blade sweep will not necessarily be killed. Near collision event observations identified raptors slowing down or increasing their flight speed to let the turbine blade go above them or go through the blade sweep before the blade came down on them. Other observations include raptors rapidly dropping or increasing their flight height to go either above, below, or around the turbine blades (in such instances raptors were near the edge of blade sweep).

With >6,960 observations and over the 368 hours of observation at the wind farm it was evident that raptors were still migrating through the ESWF in significant numbers. The current literature identifies that the extent of the disturbance that wind farms may have on raptors is still not entirely clear. The large scale avoidance of offshore wind farms has been found in some bird groups elsewhere in the world, such as waterfowl in Denmark which were found to avoid a wind farm and the near vicinity by up to 3 km (Christensen *et al*. 2004; Kahlert e*t al*. 2004). This does not appear to be the case with migrant raptors at Erie Shores as they were observed passing directly over top of wind turbines. The fact that so many raptors have been observed & killed in the Altamont Pass Wind Resource Area and in Spain, also suggests that the turbines do not cause large scale abandonment of routes by migrant and wintering raptors.

Turbine Blade Orientation and Direction of Bird Movement

Closer examination of the observations of raptors within the risk zone of height and distance out from the turbine resulted in identifying an interesting association with wind direction, turbine blade orientation and direction of dominant bird migration. The influence that wind direction has on the position of the turbine blades and how that influences collision risk has been rarely discussed in the literature to date. The wind turbines at the ESWF always face into the wind and therefore as wind direction changes so does the position of the turbine blades in relation to the lakeshore edge. Raptors and other birds may be able to avoid collisions because of the direction of bird movement in relation to the orientation of the turbine blades. The majority of raptors at ESWF were observed moving west. Therefore winds must be coming from the east or west in order to have the turbine blades moving perpendicular to the movement of raptors and create the greatest zone of risk. East or west winds were seen on 17 of 65 observation dates (26% of survey dates) over 2006 and 2007. The degree of risk decreases with winds coming from any other directions, with the lowest risk existing with south or north winds. During north or south winds turbine blades become parallel to the direction of typical movement by migrant raptors in the wind farm. Based on the thirteen year trends at nearby Hawk Cliff the dates with the biggest raptor flights coincide with winds with a northern component, which would result in birds moving parallel or close to parallel with the turbines blades (Hawk Cliff 2007). Under north or south winds (little or no migration occurs with south winds) raptors are at the least risk of collision because if they are typically moving east to west, the danger zone is still 41.5m to 118.5m above ground but the width of the risk area is minimized to only the width of the turbine blades themselves. Almost half (43%) of all risk zone observations occurred under conditions when raptors could move parallel to the turbine blades. The thirteen year trends from Hawk Cliff (2007) also indicate little to moderate migration taking place during east or west winds, when raptors would be moving perpendicular to the turbine blades. Further studies should be conducted to extend this logic and identify whether turbines on the Lake Huron shoreline would pose a greater risk to migrant raptors, as i.e. under north winds, turbines would be perpendicular to raptor flight direction.

Collision Risk

Collision risk models incorporate abundance and flight height data and are often used for pre-construction surveys to assess the potential for collision mortality. This has resulted from the absence of any significant amount of individual species data available from operational wind facilities (de Lucas *et al*. 2008; Western EcoSystems Technology Inc 2000; Smales 2005; Whitfield & Madders 2006[a]; Whitfield & Madders 2006[b]). Collision risk models, assume a positive relationship between abundance and mortality, but recent studies have begun to contest the validity of this assumption (de Lucas *et al*. 2008; Madders & Whitfield 2006).

Collision risk models based on flight height and abundance data alone are flawed and very likely overestimate collision risk. The value of post-construction monitoring is that it allows for the combined assessment of flight heights with the distance out from a turbine in order to assess actual risk to raptors. Analyzing flight height and distance from turbines together is a much more reliable predictor of collision risk, as it is not based on assumptions.

If the flight height data from Erie Shores were solely used (like in collision risk models) it would suggest that 27% of raptors are at risk of collision. But, data on the distance out that raptors passed the turbines, would indicate only 11.1% of raptors at risk of collision, regardless of their flight height.

When flight height and distance from the turbine data were combined for ESWF, 3% (n= 159) of raptors were in the risk zone. At the same time, however, all 3% of the raptors observed in the risk zone survived. Assessing risk by flight height or distance out from turbine individually fails to account for situations where a raptor may be in the risk zone for flight height, but could be 150m out from the turbine and therefore at no risk of collision. Therefore without combining data on both flight height and distance out from the turbine it becomes easy to over estimate collision risk. It is therefore important to also recognize that being in the risk zone does not automatically equate to collision mortality. If that was the case then at least 159 raptor fatalities should have been found at ESWF.

Unfortunately there are gaps in the peer reviewed literature in regards to combining both flight height data and the distance out from the turbines birds pass, thus inhibiting the ability for comparison with other wind farms.

Based on analysis of my study's findings and those at other wind facilities I recommend that collision risk assessments for raptors should include the following information: prey density, raptor flight direction, prevailing wind direction, abundance of individual raptor species, type of flight and flight height. These are all variables which appear to influence raptor mortality and that can be collected as part of pre-construction monitoring. Baited live traps for rodents and small mammals can be used to identify what species are present and determine their abundances in the various habitats within the proposed wind farm study area. Understanding prey densities can identify specific habitat types or potentially entire study sites which support high prey abundances, and therefore may be more likely to experience increased risk of raptor collision mortality. Behavioral observations, using the same methods used in my study, can provide information on raptor flight direction, types of flight and flight heights. Type of flight and flight heights are variables which allow for comparison of pre and post-construction monitoring data. Raptor Flight direction data can be used in conjunction with data on prevailing wind directions to identify the proportion of time that turbine blade orientation would pose the greatest risk to raptors based on their dominant flight directions for a study area. Wind direction data from the weather station(s) put up by the wind developer of a proposed project should be used as it would provide accurate on-site information.

2) How far out from turbines do migrant raptors keep when passing a wind turbine?

Distance from Turbine

Most raptors maintained distances well out from operational turbines (11.3% of raptors regardless of their flight height), with many of the raptors that ventured within the blade sweep distance out from the turbines, only doing so when their flight heights kept them out of risk of collision . With raptors observed passing through the blades of operating turbines, it is evident they are keenly aware of whether the rotor is spinning or not, at new generation turbines.

The data on migrant raptors at the ESWF appears to be similar to what has been found for raptors at other wind farm locations both in North America and in Europe (which largely comprised of non-migrant raptor observations). In Spain two raptor species (griffon vultures and short-toed eagles *Circaetus gallicus)* often maintained distances of 50-250m out from turbines (Barrios & Rodriguez 2004). The findings at the ESWF are in line with Buffalo Ridge Phase I and the PESUR & E3 Wind Farms in Spain which indicate the majority of raptors keep out of the blade sweep distance (Barrios & Rodriguez 2004; Osborn *et al.* 1998). In Spain, 94% (n=78) observations of raptors within 5m of turbines, occurred when the turbines were off, suggesting there is likely some stimuli from operating turbines which contributes to making birds stay outside of the risk area. Overall there is limited published literature on the distances at which raptors will pass wind turbines and this is a topic warranting further investigation, especially in different landscapes.

3) What are the flight heights above ground that migrant raptors most frequently fly at to pass wind turbines?

Flight Heights

Flight height observations from both pre-construction and post-construction studies at several wind facilities (Erie Shores, Buffalo Ridge, Maiden and Foote Creek Rim Wind Farms), suggests blade sweep height is not the height above ground where raptors are most frequently observed, see Table 12. Raptor flight height observations from Erie Shores, Buffalo Ridge, Maiden and Foote Creek Rim Wind Farms indicate the majority of raptors fly at height outside of the blade sweep.

The findings of pre-construction and post-construction survey data on flight heights do seem to vary. Post-construction surveys at the Erie Shores Wind Farm and Buffalo Ridge show 20-31% of raptors at blade sweep height, while pre-construction surveys at the Foote Creek Rim and the Maiden Wind Farm show a range of 45-48% of raptor observations being at blade sweep height, refer to Table 12 (Western EcoSystems Technology Inc. 2000; Western EcoSystems Technology Inc & Northwest Wildlife Consultants Inc. 2002). These differences may be the result of overestimating raptor flights at blade sweep height due to the inherent inaccuracies of flight height estimates when turbines are not present to act as a reference for estimates. This is an obvious flaw of comparing flight height data from pre-construction to post-construction. The difference between pre-construction and post-construction study findings may also be due in part to the modification of flight heights by raptors due to the presence of turbines or it could be a combination of the above mentioned factors.

Species data from a variety of wind farms, shown in Table 12, indicate that flight heights for individual species of raptors can vary from that of summary data of raptors as a group. Based on data from three wind farms in different locations in the United States, American kestrels appear to most frequently fly at heights above or below blade sweep height (West Inc. 2005; Western EcoSystems Technology Inc & Northwest Wildlife Consultants Inc. 2002; Osborn *et al.* 1998). In contrast northern harriers fly almost exclusively below blade sweep height at a variety of locations and at both proposed and existing wind farms (Whitfield and Madders 2006).

For the red-tailed hawk, blade sweep height observations at proposed wind farms range from 58-68%, while at operational turbine locations (Buffalo Ridge and APWRA) flight heights above or below the blade sweep height dominate (Hoover & Morrison 2005; Osborn *et al*. 1998).

Overall, individual species data indicates some species have dominate flight heights, and that dominant flight heights may vary between pre-construction and post-construction conditions. Without further study and at a greater variety of locations it is unclear to what extent geographic location and turbine layout may influence variation in species flight heights.

CONSIDERATION OF CUMULATIVE IMPACTS

The mortality at the APWRA and the Tarifa, Spain wind farms, which are notorious for high levels of raptor mortality, are 40 to 70 times greater than mortality both found and estimated for the ESWF, however the scale of the wind facilities are completely different. How mortality rates increase with wind facility size is currently unclear. It therefore becomes important that the cumulative impact of multiple wind facilities along the north shore of Lake Erie be assessed as more wind farms are made operational. Cumulative impact analysis for all wind farms along the Lake Erie shoreline needs to be considered because raptor mortality at individual energy facilities may be small. Combining mortality data from multiple facilities may identify broader raptor mortality trends and may be more appropriate for comparison with the APWRA where thousands of turbines are operational.

As pointed out earlier, however, it's not just the numbers of turbines at APWRA, but their layout (tightly spaced), design (perches and high rotation speeds) and biological factors (abundant prey base) that may be crucial. It might be that hundreds of new generation turbines could be placed along the Lake Erie shore and, because of their layout and design and land-use activity in that area (active agricultural croplands), relatively low mortality would result. With multiple operational facilities along the Lake Erie migration route larger numbers of raptors may be forced to hunt within wind farms. Raptors may then become distracted by prey and thus made more vulnerable to collision. Also as you move farther southwest along the main migration route the abundance of raptors increases greatly (it is unclear at what level of abundance, abundance may become a contributor to the amount of mortality, if at all). There is also concern over raptors becoming habituated to the turbines because there will be so many turbines, which may cause raptors to pay less attention to them. Cumulative impacts should also be evaluated based on year round data at all facilities in Ontario and include wind farms sited in important areas like raptor wintering, migration, and breeding areas. In order to properly determine cumulative effects for all Ontario wind facilities it becomes important that the governing agencies ensure consistent monitoring approaches and effort are taken for all wind farm studies. Mortality rates need to also be calculated the same way for all facilities to allow comparison between wind farms and for ease of determining cumulative mortality estimates.

Mortality of raptors at all Ontario wind farms has not yet been determined by governing agencies. It is therefore important to take a 'conservative' approach to turbine placement along the entire Lake Erie shoreline, as the estimated mortality rate for raptors at all wind turbines in Ontario combined, is not yet known. Erie Shores represents just a single study. More studies are needed to determine if the pattern (low mortality) at ES extends more broadly along the Great Lakes shorelines, and to determine what contributes to this pattern; is it a function of migration (birds moving through), habitat (causing birds to hang around for rodents), prevailing wind direction, something else?

CONCLUSION

The mortality rate for raptors at Erie Shores was found to be in the lower end of mortality for modern generation wind farms outside of California.

The estimated autumn mortality rate for ESWF was found to range from 0.028 to 0.049 raptors/MW/year, based on four fatalities over two years. Despite being in a migration route where hundreds of thousands of raptors migrate the autumn level of raptor mortality was 42 to 70 times less than that estimated at the APWRA in California. Comparison between the average annual counts for Hawk Cliff, ON and the Golden Gate Raptor Observatory, Ca indicates greater numbers of migrants raptors are annually observed in Ontario at Hawk Cliff. Despite the apparent greater abundance of raptors migrating along the north shore of Lake Erie, the level of mortality was low compared to what has been found in California.

Fifteen species of raptors were observed passing wind turbines at the Erie Shores Wind Farm. No individual species was found to be more prone to fatalities than any other, since multiple fatalities of specific species were not found.

With two fatalities found per year it appears that simply the presence of high numbers of raptors does not automatically equate to high raptor collision mortality. The data from ESWF, however, suggests the need for further investigation by future studies into whether the percent composition of individual raptor species may provide an indication of the susceptibility of the species to collision mortality, as despite the low sample size, raptor fatalities at ESWF comprised of the four most abundant species observed.

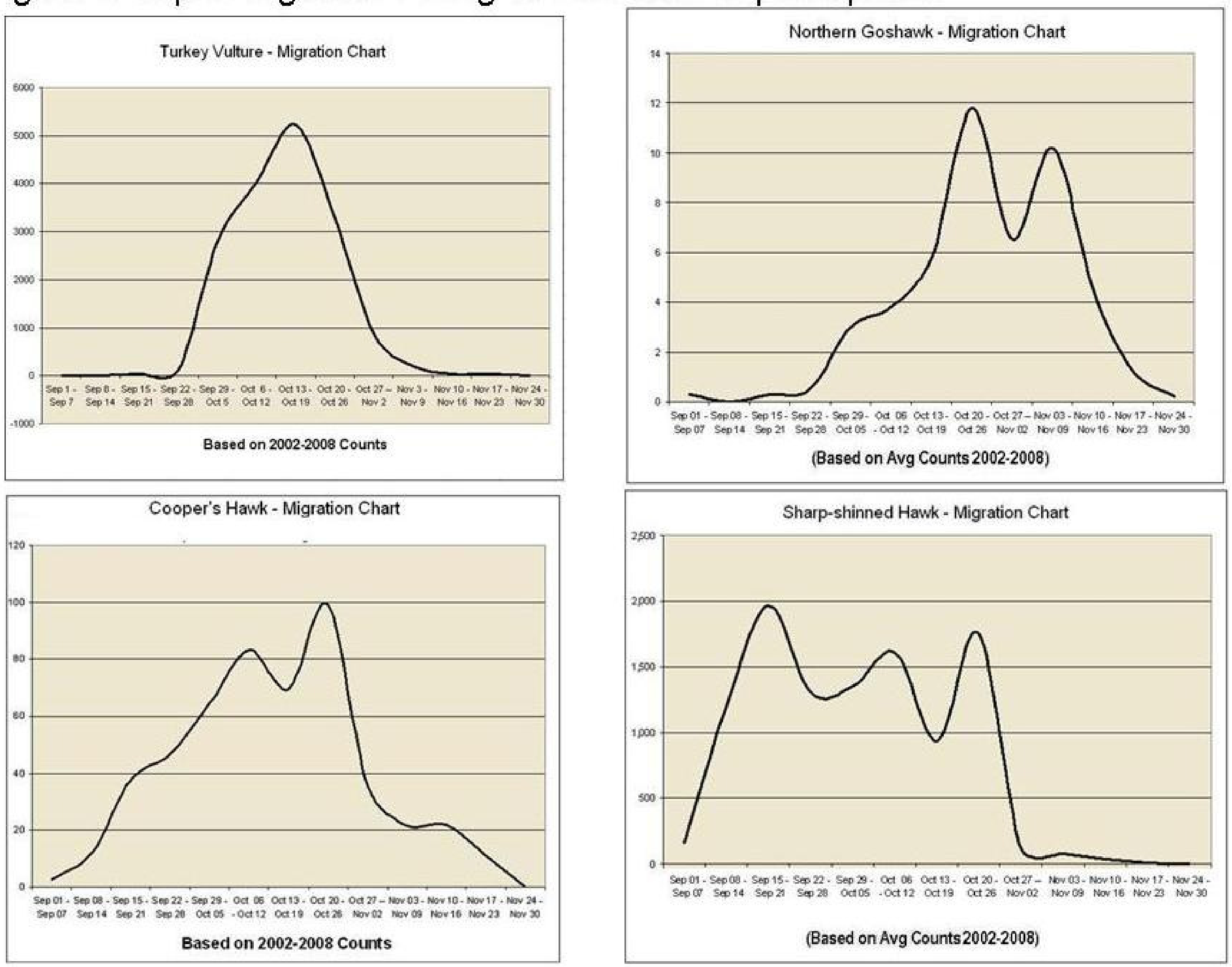
A raptor entering the risk zone does not automatically equate to a turbine collision mortality. Only 3% of raptors observed entered the actual risk area, however, all of those birds survived since none of those raptors were observed being hit or were found during mortality searches.

Findings of the presented study suggest the need for further detailed study on the use of hedgerows and woodlots by migrant raptors and their influence on where raptors pass turbines, so that we understand the extent that these landscape features may influence collision risk behavior situations and mortality. Factors such as flight behavior characteristics of certain species, landscape features and weather conditions are potentially more influential factors than raptor abundance alone and also warrant further investigation. Mortality at Erie Shores may be limited despite being in a migration corridor as a result of the following conditions being present:

- New tubular design turbines
    - Lower revolutions per minute of turbine blades (slower blade movement)
    - No lattice towers and therefore no perching opportunities. Several companies have proposed using lattice towers in ON in recent years because of their lower cost compared to tubular towers. So far, this design has not been approved by government agencies.
- Being sited in a flat open landscape of active agricultural crops
- Habitat conditions underneath the turbines: Erie Shores has mainly Intensive agriculture crops under turbines vs. old fields, fallow fields, etc (Such as at Wolfe Island). Siting turbines in areas of low prey density might therefore be one of the most important factors in reducing raptor mortality
- Large separation distances between turbines
- Westerly direction of migrant raptor movement, versus dominant wind directions and preferred wind directions for major raptor migration movements.

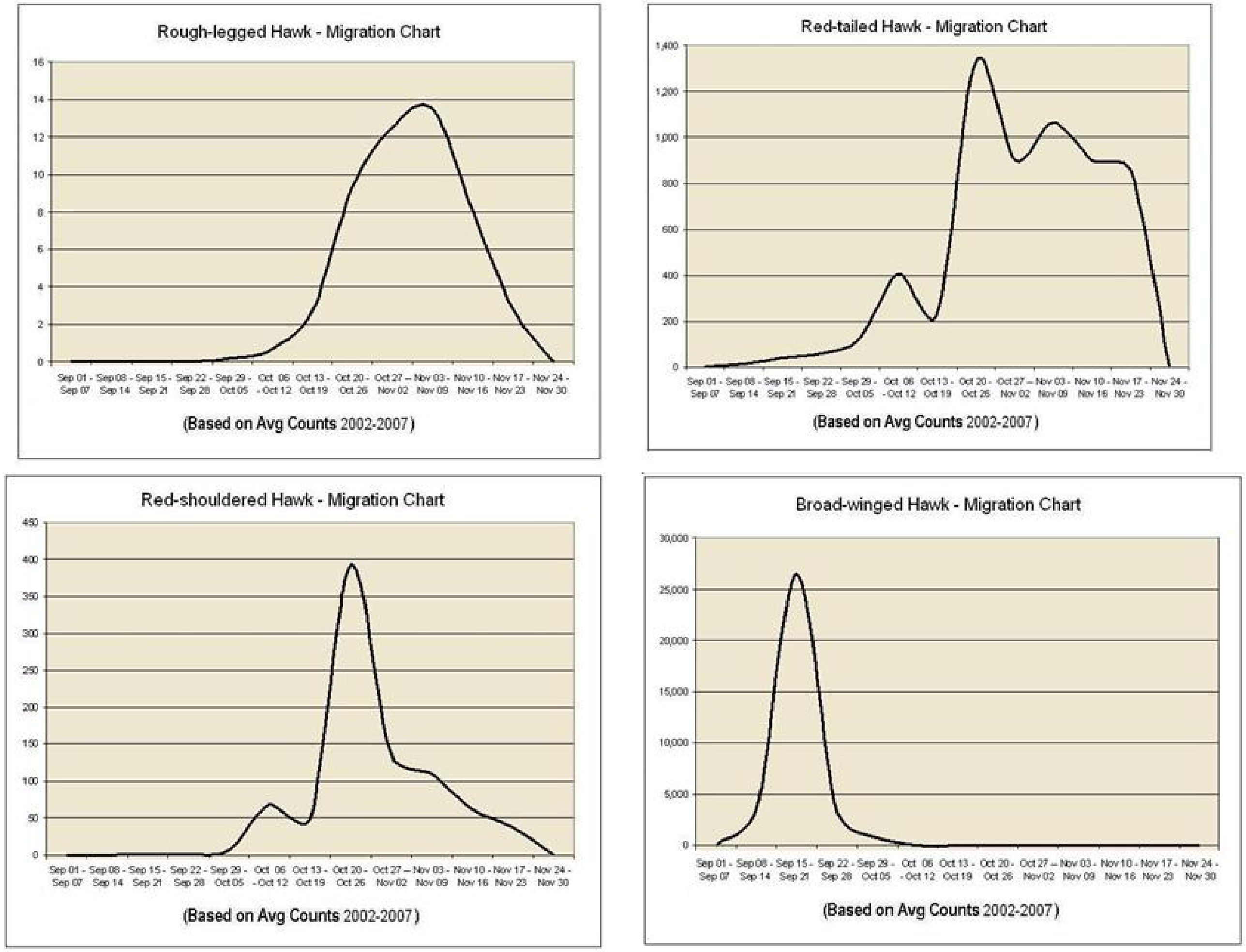
Variables such as 'old technology' turbines, as was shown in the study by Smallwood and Karas (2009), distance between turbines, landscape eg. ridgelines or valleys vs. lakeshore edge, raptor flight characteristics, land use practices etc. are likely greater influences on causing mortality or interact in some way to cause mortality, than simply the abundance of raptors. The present study at ESWF is the first study to take place along an important raptor migration corridor in eastern North America, and additional studies are needed to determine whether low raptor mortality is a widespread phenomenon.

Figure 1. Raptor Migration Timing for Individual Raptor Species



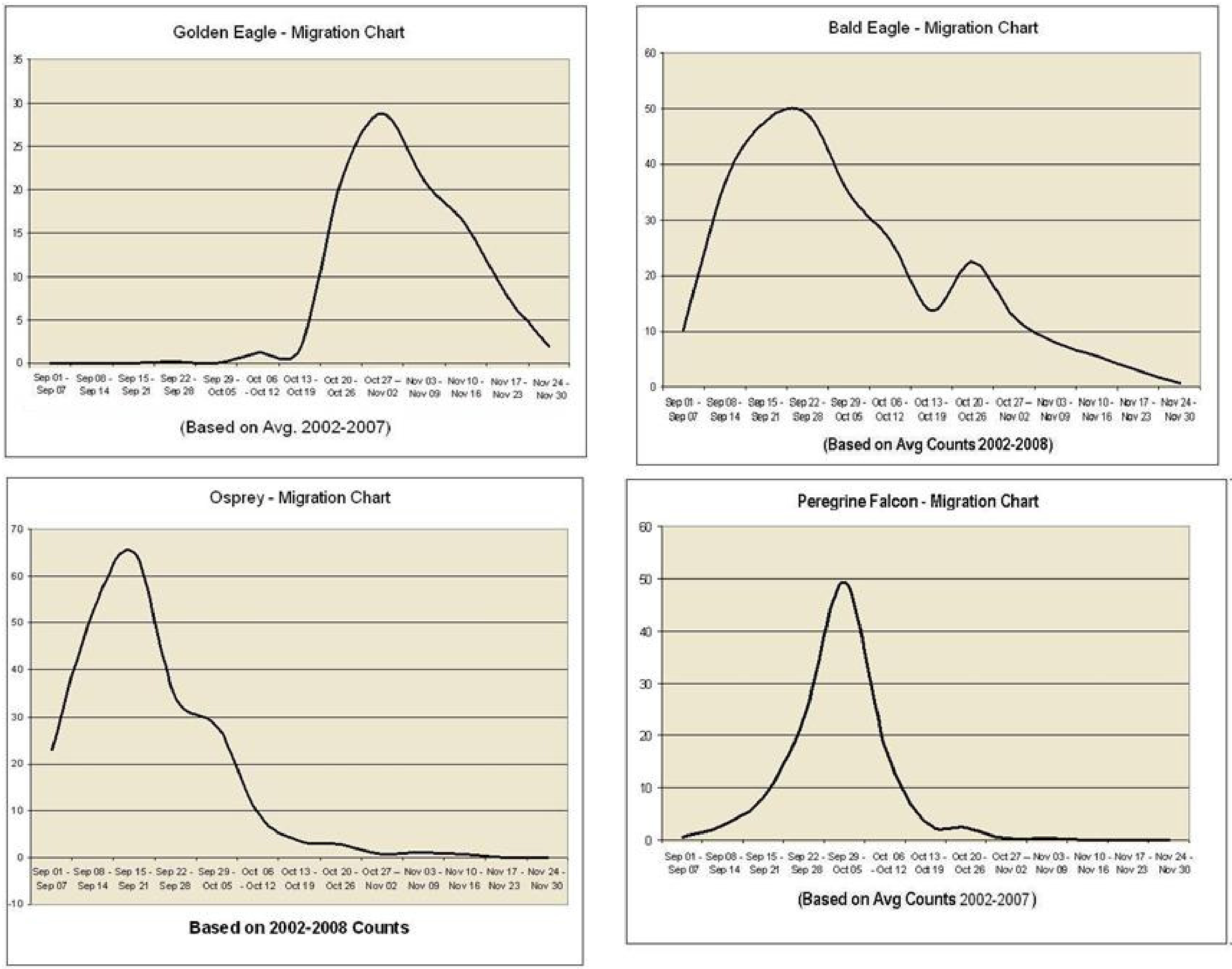
(Source: http://www.ezlink.ca/~thebrowns/HawkCliff/hcf_species_info)

Figure 2. Raptor Migration Timing for Individual Raptor Species, Cont'd



(Source: http://www.ezlink.ca/~thebrowns/HawkCliff/hcf_species_info)

Figure 3. Raptor Migration Timing for Individual Raptor Species, Cont'd



(Source: http://www.ezlink.ca/~thebrowns/HawkCliff/hcf_species_info)

Figure 4 Environment Canada Mortality Rate Calculation

A) Determining Searcher Efficiency Values
Calculating Individual Searcher Efficiencies

$$Se = \frac{\text{Number of Carcasses Found by Observer}}{\text{Number of Carcasses Placed out for Searcher Efficiency Trials}}$$

Individual 1:	Individual 2:	Individual 3:
Se = 23 / 30	Se = 21 / 28	Se = 19 / 22
=0.77	= 0.75	= 0.86
=77% found	= 75% found	= 86% found

Average for All Searchers Combined:
Se = 23+21+19 /80
= 63/80*100
= 79% found

James Searcher Efficiency(small to medium birds)
Se = 22/28
= 0.79 (79%)

Searcher Efficiency Calculation for the Wind Farm

Se = (Searcher efficiency for searcher group 1(Dance) x Proportion searched) + (Searcher efficiency for searcher group 2 (James) x Proportion searched)		
A) Lowest Individual Searcher Efficiency = (0.75)(0.2*) + (0.79)(0.8**) = 0.15 + 0.632 = 0.782	**B) Average Searcher Efficiency/James' Searcher Efficiency** = (0.79)(0.2) + (0.79)(0.8) = 0.16 + 0.632 = 0.792	**C) Highest Individual Searcher Efficiency** = (0.86)(0.2) + (0.79)(0.8) = 0.172 + 0.632 = 0.804
*= proportion of turbines searched by Dance = 12 / 66 turbines = 0.2 (20%)		
** = proportion of turbines searched by James (shown as area not covered by Dance et al despite him covering 100% of turbines) = 54 / 66 turbines = 0.8 (80%)		

B) Proportion of Area Searched Calculation

Area covered by the Mortality Searched (40m)	**If only 60% of all turbines was searched**
$= \prod r^2$ $= 3.14(40)^2$ = 3.14(1600) = 5024m^2 **/turbine**	Area of turbine *Percent searched =5042* 0.6 =3014.4 m^2 **/turbine**
Proportion of Area Searched Ps = (3014.4 m^2* 66 turbines) / (5024 m^2 * 66 turbines) = 198,950.4/331,584 = 0.6	

Figure 5 Calculation of Seasonal Mortality, Environment Canada Method

Formula for Seasonal Mortality:

$$C = c / (Se \times Sc \times Ps)$$

C = the corrected number of bird or bat fatalities
c = the number of carcasses found
Se = the proportion of carcasses expected to be found by searchers (searcher efficiency)
Sc = the proportion of carcasses not removed by scavengers over the search period
Ps = the percent of the area searched (measured as a % of a 50 m radius around the turbine base

Estimated Total Number of Birds Fatalities for Entire Wind Farm per Year

Highest Estimate for Mortality	Lowest Estimate for Mortality
C = c / (Se x Sc x Ps) C = 2 / 0.782 x 0.89 x 0.6 C = 2 / 0.417588 C = 4.789 birds/autumn	**C = c / (Se x Sc x Ps)** C = 2 / 0.804 x 0.89 x 1 C = 2 / 0.71556 C = 2.795 birds/autumn

Number of Raptor Fatalities per Turbine and per MW per Autumn

High Range for Mortality: (assuming 40% of area under all turbine not searched)		**Low Range for Mortality:**	
Number of Raptors /turb/autumn (Rt)*	*Number of Raptors /MW/autumn*	*Number of Raptors /turb/autumn (Rt*)*	*Number of Raptors /MW/autumn*
Rt = C / 66 turbines = 4.789 / 66 = 0.073 raptors/turbine/autumn	**= Rt / 1.5 MW** = 0.073 / 1.5 = 0.049 raptors/MW/autumn	**Rt = C / 66 turbines** = 2.795 / 66 = 0.042 raptors/turbine/autumn	**= Rt / 1.5 MW** = 0.042 / 1.5 = 0.028 raptors/MW/autumn
* Rt = number of raptor fatalities per turbine per season			

Figure 6

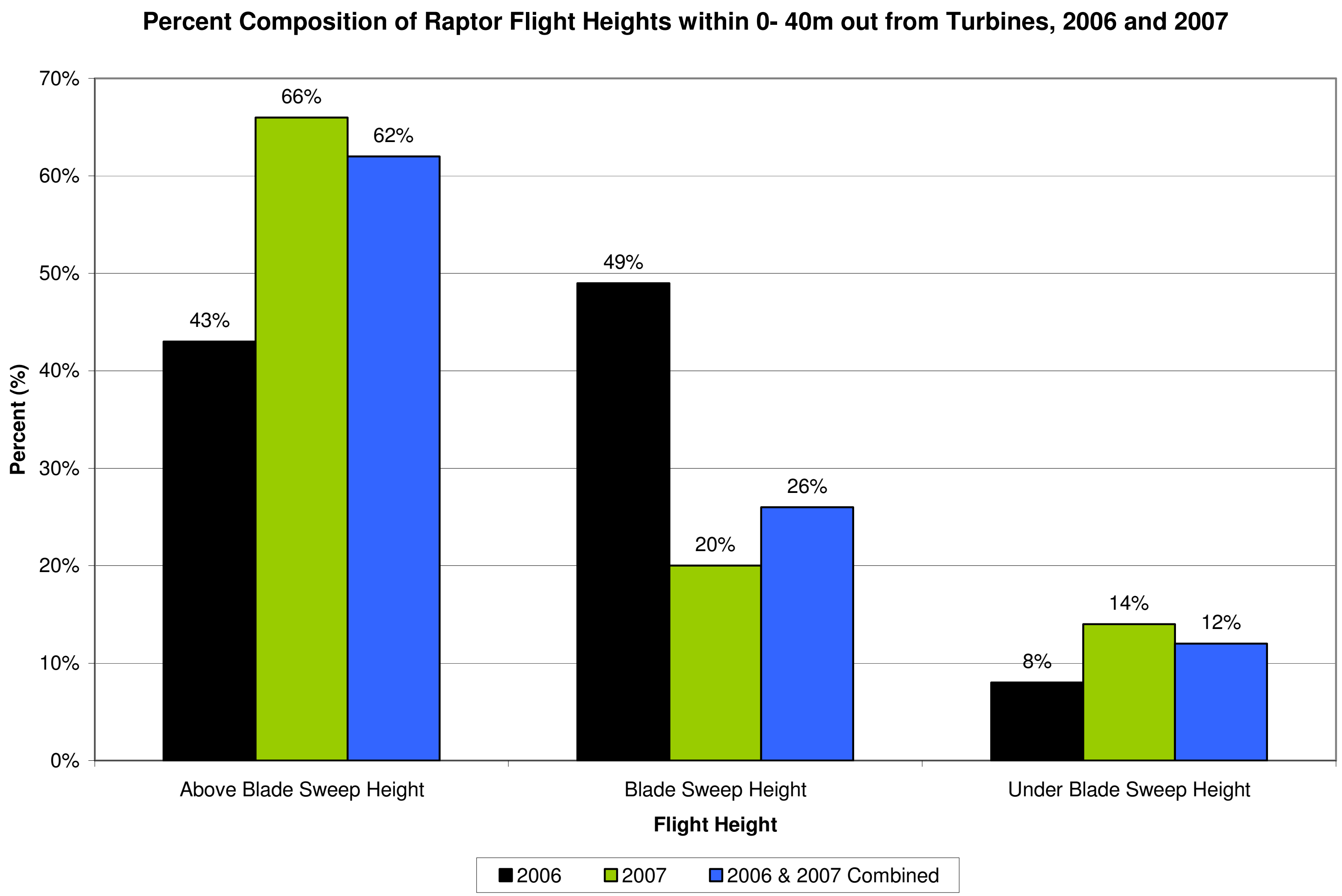
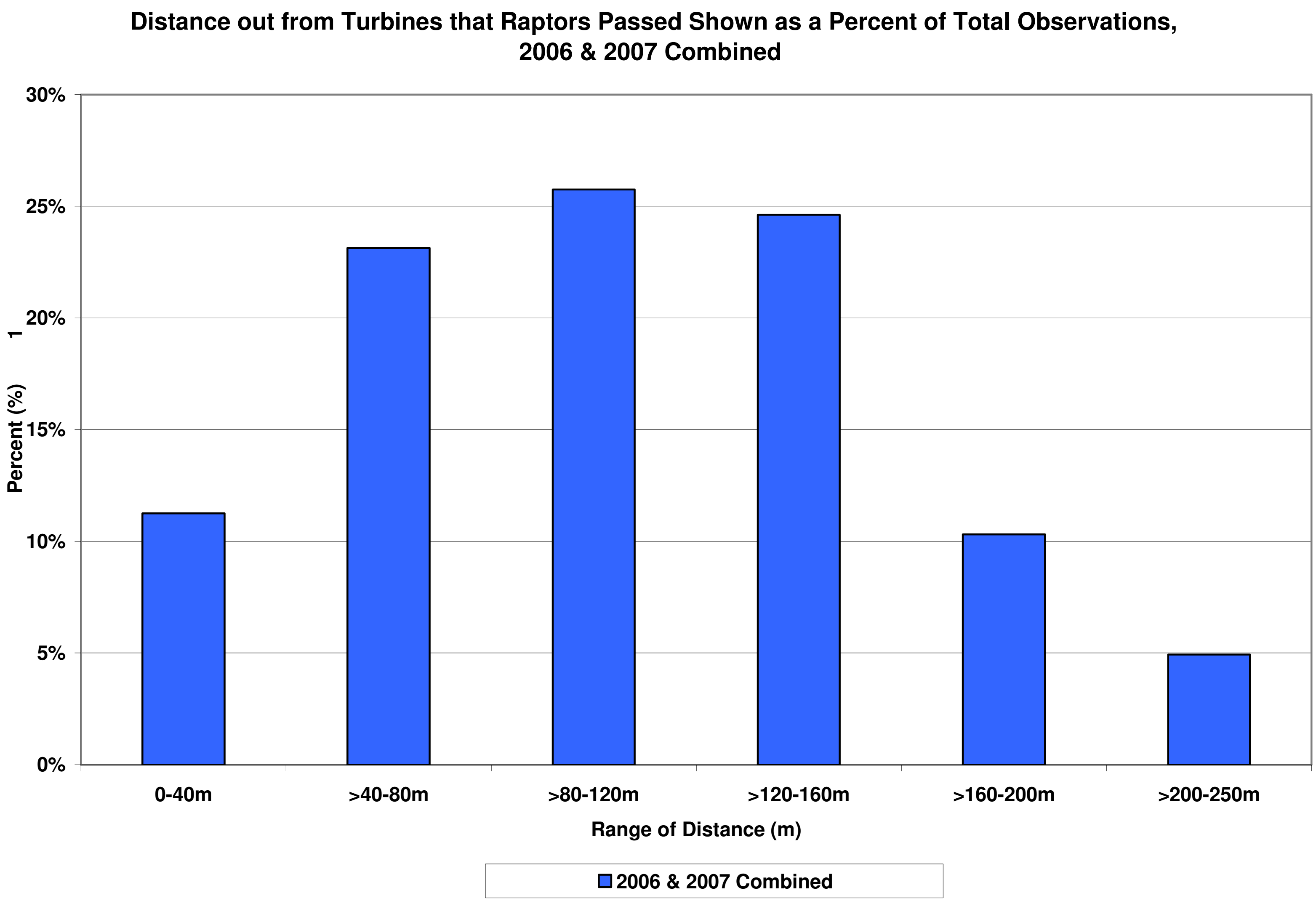

Percent Composition of Raptor Flight Heights within 0- 40m out from Turbines, 2006 and 2007
70%
60%
50%
40%
30%
20%
10%
0%
Percent (%)
66%
62%
43%
49%
20%
26%
14%
12%
8%
Above Blade Sweep Height
Blade Sweep Height
Under Blade Sweep Height
Flight Height
2006
2007
2006 & 2007 Combined

Figure 7



Distance out from Turbines that Raptors Passed Shown as a Percent of Total Observations, 2006 & 2007 Combined
30%
25%
20%
15%
10%
5%
0%
Percent (%)
1
0-40m
>40-80m
>80-120m
>120-160m
>160-200m
>200-250m
Range of Distance (m)
2006 & 2007 Combined

Figure 8

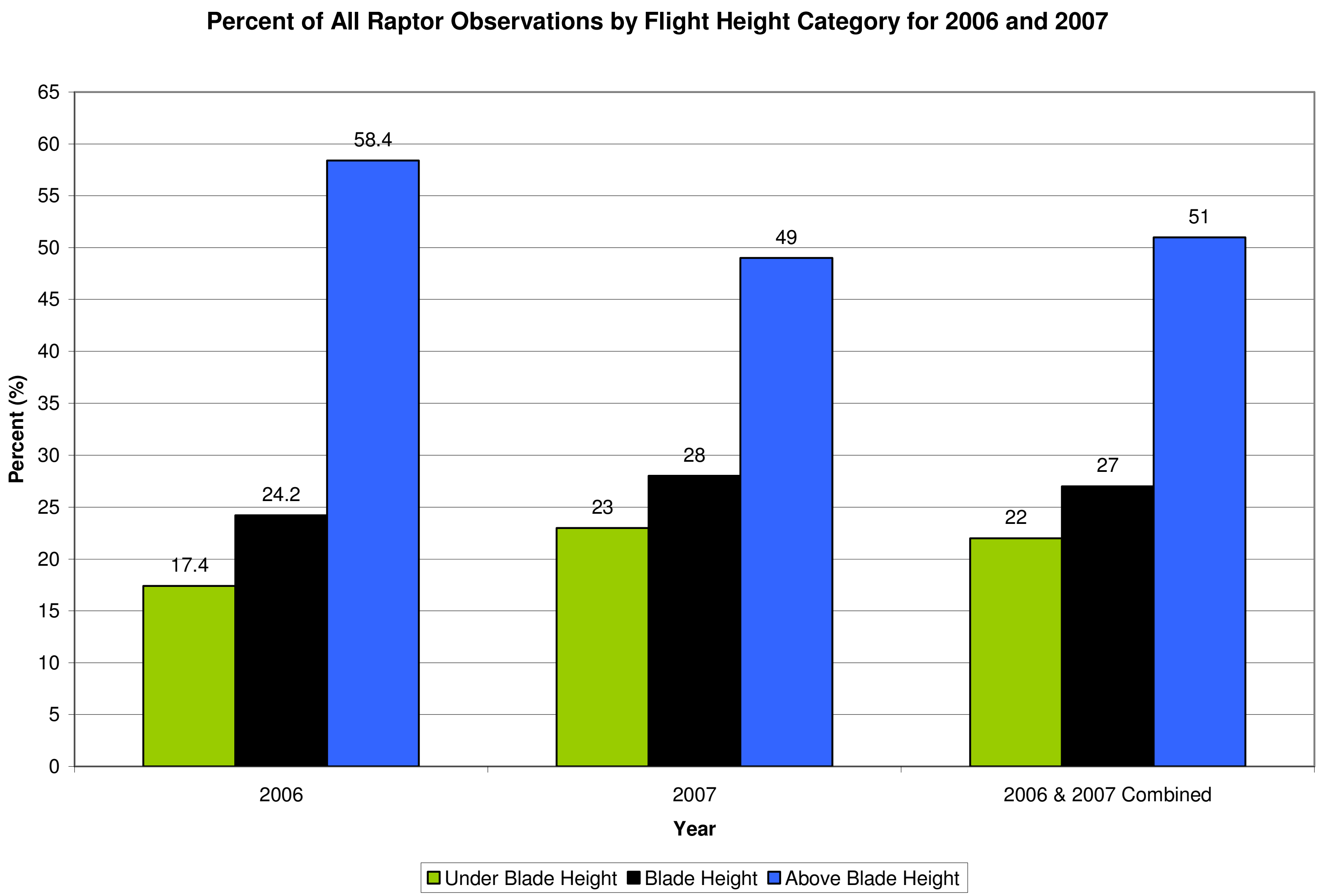

Percent of All Raptor Observations by Flight Height Category for 2006 and 2007
Percent (%)
65
60
55
50
45
40
35
30
25
20
15
10
5
0
17.4
24.2
58.4
23
28
49
22
27
51
2006
2007
2006 & 2007 Combined
Year
Under Blade Height
Blade Height
Above Blade Height

Table 1. Number of Observations for each Raptor Species Observed and the Overall Percent Composition by Species over 2006 and 2007 Combined

		Number of Observations at Erie Shores*				Hawk Cliff Data**		
Species	Scientific Name	2006	2007	Combined	Percent of all Observations (%)	Average Seasonal Count (2000-2010)***	Maximum Seasonal Count	Maximum Daily Count
Turkey Vulture	*Cathartes aura*	687	1897	2584	37.9	15,195	25,567	5,479
Northern Goshawk	*Accipiter gentilis*	4	29	33	0.5	44	69	18
Cooper's Hawk	*Accipiter cooperii*	98	238	336	4.9	401	637	96
Sharp-shinned Hawk	*Accipiter striatus*	401	1137	1538	22.5	8,093	16,643	1,949
Accipiter sp.		0	18	18	0.3	-	-	-
Northern Harrier	*Circus cyaneus*	36	112	148	2.2	919	2116	252
Rough-legged Hawk	*Buteo lagopus*	0	23	23	0.3	40	110	32
Red-tailed Hawk	*Buteo jamaicensis*	139	1057	1196	17.5	4,874	11,148	3,459
Red-shouldered Hawk	*Buteo lineatus*	20	38	58	0.9	729	1,134	393
Broad-winged Hawk	*Buteo platypterus*	7	3	10	0.1	42,484	135,336	130,640
Buteo sp.		37	60	97	1.4	-	-	-
Golden Eagle	***Aquila chrysaetos***	**5**	**20**	**25**	**0.4**	**113**	**220**	**65**
Bald Eagle	***Haliaeetus leucocephalus***	**46**	**224**	**270**	**4.0**	**238**	**406**	**62**
Eagle sp.		0	1	1	0.0	-	-	-
Osprey	*Pandion haliaetus*	10	22	32	0.5	176	361	57
Peregrine Falcon	***Falco peregrinus***	**8**	**41**	**49**	**0.7**	**92**	**148**	**47**
Merlin	*Falco columbarious*	20	46	66	1.0	131	265	38
American Kestrel	*Falco sparverius*	146	191	337	4.9	3,069	5,076	1,187
Total Number of Observations		**1664**	**5157**	**6821**				

* Based on observations at all distances from turbine

** Data from Hawkcount.org, retrieved Sept 9, 2009

http://hawkcount.org/siteinfo.php?rsite=392&PHPSESSID=2703c7f387f6b01d340a99dca7fc9db2
***Average Seasonal Count, Maximum Seasonal Counts, Maximum Daily Counts are based on an 11 year period (2000-2010)
Bold indicates that the species is a Species at Risk provincially or federally

Table 2 Site Conditions and Turbine Separation Distances at the Twelve Turbines Studied at the Erie Shores Wind Farm

Turbine	Distance to Bluff (m)	Closest Turbine Number	Distance to Closest Turbine (m)	Vegetation Cover in Search Area*
63	93	61	463	Soybean, gravel pad and road, grasses and weeds
61	103	63	463	Soybean, asparagus, rye, gravel pad and road
52	130	55	821	Grass, gravel pad and road, asparagus
42	146	44	810	Young apple orchard with grass and weed ground cover, gravel pad and road
47	953	48	383	Soybean, gravel pad and road
48	1306	47	383	Scattered grass and weeds, mini pumpkins and squash, gravel pad and road
12	209	10	365	Corn field, gravel pad and road
10	264	8	355	Soybean, gravel pad and road, scattered grasses and weeds
8	659	10	355	Corn field, grasses and weeds, gravel pad and road
11	1047	9	358	Corn field, gravel pad and road, grasses and weeds
6	200	7	448	Corn field, gravel pad and road
7	126	6	448	Soybean, deciduous forest edge, gravel pad and road

*** Vegetation cover is listed in order most to least dominant vegetation cover in the search area**

Table 3 Mortality Search Effort During 2006 and 2007 at ESWF

Year	Season	Dates	Search Frequency	Time of Searches (Minutes)
2006	Autumn	*James:* August 16th to November 14th *Dance:* September 18th to December 4th	*James:* • 33 turbines -searched once a week • 33 turbines -searched every other week *additional searches during days with heavy migration (some lakeshore turbines as often as 2-3 times a week) Dance: 12 turbines –once a week to every other week	*James:* 15 minutes *Dance:* 10 minutes
2007	Autumn	*James:* August 21st to November 8th *Dance:* September 5th to November 28th	*James:* • 66 turbines searched once a week *Dance:* • 12 turbines -most turbines searched once a week by Dance *From October to November 28th all twelve turbines were searched at least once a week and some as frequent as 2-3 times in some weeks	*James:* 25-30 minutes (up to 45 minutes) *Dance:* *15-20 minutes*

Table 4 Behavioral Observation Survey Dates and Weather Conditions, 2006

Date of Visual Observations		Number of Observers	Weather Conditions: Temp. (°C)	Wind Direction	Wind Speed (Km/h)	Cloud Cover (%)	Precipitation	Precipitation Previous 24hr
September	18	1	20	S	21-40	90	0	0
				SE @ 12:00				
	19	1	15	W	21-40	80-85	0	rain (a lot)
	24	2		NW	21-40	50	0	0
	25	2	12	SW	6-12	0	0	0
	26	1	16	NW	2-5	10-15%	0	0
				W from 10:30 to 13:40				
				S @ 14:25				
	27	1		S	13-20	25-30%	0	0
October	2	1	7	S	2-12	75%	0	0
	8	2	15	S	6	0	0	0
	9	2	15	SW	2-5	10-15%	fog (until 9:51)	0
	15	1	4	W	21-30	20%	0	rain
	16	1	11	E	1	40%	0	0
				S @ 10:24	12	80%		
	30	2	7	S	13	5-10%	0	rain and snow
November	1	1	7	W	17-21	80-85	0	0
	4	1	5	WNW	3	50%	0	snow
				SW @ 12:30	6			
	6	1	13	S	7-12	5%	0	fog on drive to site
	12	1	4	NE	9-11	90%	0	rain

			4	N @ 12:00				
	13	1	3.9	NE	8	100	light drizzle, high fog	0
							dirzzle stopped @ 10:34, but still fog	
	14	1	6	W	2-4	90-100%	0	rain
				NW @ 9:50	8	100%		
				W @ 11:30			light drizzle	
	23	1	3.5	NE	13	10-20%	fog until 9:30	0
				N @ 10:20				
	25	1	8.1	S	11	10-15%	0	0
					12 @ 13:02			
	26	1	11	SW	11	60-70	0	0
				W by 2:47				
December	4	1	-2	W	19	50-90%	0	snow
					20 @ 13:00		flurries	
Total Number of Days		**22**						

Table 5 Behavioral Observation Survey Dates and Weather Conditions, 2007

Date		Number of Observers	Weather Conditions: Temp. (^oC)	Wind Direction	Wind Speed (km/h)	Cloud Cover (%)	Precipitation	Precipitation Previous 24hr
August	22-Aug	2	Un	S	0-5	Un	0	0
September	5-Sep	2	26	SE	6	20-30	0	0
	8-Sep	2	22	N	7	50	0	0
	11-Sep	1	17	W	17	11	0	rain
	14-Sep	2	22	SW	17	5	0	0
	19-Sep	1	20	S	11	5	fog	0
	21-Sep	1	21	SSE	10	70-80	0	0
	22-Sep	1	28	W	10	50	0	0
	26-Sep	1	22	SW (shifted N by 14:47)	10	100	rain	rain
October	2-Oct	1	18	S	20	100	rain	0
	3-Oct	1	19	SSW	32	100	rain (off and on)	rain
	4-Oct	2	18	SE	4	15-20	fog	rain
	6-Oct	2	27	WSW	11	15-20	0	0
	10-Oct	1	13	W	27	30-35	0	rain
	11-Oct	1	9	N	11	15-20	0	rain
	12-Oct	1	7	NNW	12	100	0	0
	14-Oct	2	15	NW	14	3	0	0
	15-Oct	1	15	SE	4	95	0	0
	16-Oct	2	14	NE	19	40-45	0	rain
	17-Oct	2	17	S	8	100	0	0
	19-Oct	2	19	S	28	100	0	rain
	20-Oct	1	15	W	28	98	0	rain

	22-Oct	1	20	S	8	0	0	0
	24-Oct	2	11	W	5	60-70	0	rain
	25-Oct	1	8	NE	16	20-30	0	0
	26-Oct	2	16	SE	12	100	0	0
	29-Oct	1	12	SW	25	20	0	0
	30-Oct	2	14	SW	8	0	0	0
	31-Oct	3	13	S	20	20-30	0	0
November	1-Nov	2	8	W	16	3	0	0
	2-Nov	1	2	E	5	3	0	0
	7-Nov	2	3	W	18	95	0	rain/snow
	10-Nov	2	4	NNE	16	80-90	0	rain
	13-Nov	3	10	SE	7	5	0	rain
	15-Nov	2	6	W	16	90	0	rain
	16-Nov	1	1	W	14	90	snow	snow
	18-Nov	1	0	NE	19	10	0	snow
	19-Nov	1	4	SE	14	100	0	0
	20-Nov	1	11	NW	16	50-60	0	rain
	24-Nov	2	3	SW	28	100	snow	snow
	25-Nov	1	4	SW	24	25-30	0	0
	27-Nov	1	6	SW	28	60	0	snow/rain
	28-Nov	2	3	ENE	8	70-80	0	0
Total Number of Days		**43**						

Table 6 Ross James' Mortality Search Dates and Turbines Searched on each Day, 2006

16 Aug. - 57,60,62,58,59,64,66,65,63,61,52,56,55,53,54,50,51,48,47,49,46,42,40,41,44,36,37,39, 35,34,33,27,30,29,28,26,25,43,24,23,45,22.
17 Aug. - 21,19,18,17,16,15,14,13,9,11,20,8,10,12,6,47,4,3,1,2,5,31,32,38.
23 Aug. - 62,66,65,63,61,56,42,35,43,33,39,38,32,43,27,23,18,19,17,8,10,12,11,20,9,6,7,13,14,16, 15,21,22.
24 Aug. - 24,25,26,29,30,28,31,37,36,40,41,44,46,52,49,48,47,51,50,54,53,55,57,60,58,59,64.
30 Aug. - 62,66,65,63,61,56,42,35,34,33,39,38,32,43,27,23,18,19,17,8,10,12,6,7.
31 Aug. - 24,31,37,41,47,51,49,52,57.
6 Sept. - 43,32,35,34,33,39,38,41,42,52,56.
7 Sept. - 23.22.18.19.17.13.14.20.8.10.12.3.2.5.6.7.24,25,26,27,29,30,28,31,36,46,49,48,54,57.
8 Sept. - 62,58,65,66,61,63.
12 Sept. - 40,44,37,31,25,27,23,45,16,15,18,21,62,59,64,50,47.
13 Sept. - 43,32,38,39,35,34,33,42,52,56,55,53,60,50,47,51,29.
14 Sept. - 17,6,7,4,1,9,11,8,10,12,20.
15 Sept. - 65,63,61.
19 Sept. - 41,36,39,35,34,33,38,32,43,26,27,29,28,23,18,18,16,15,21,22,27.
20 Sept. - 14,13,20,8,10,12,6,7,3,5,2,42,52,49,48,27,24.
21 Sept. - 54,56,57,62,58,63,61,65,66,46.
25 Sept. - 61,63,65,66,52,42,35,32,43,4,6,7,16,15,17,18,21,23,24.
26 Sept. - 27,30,25,31,38,37,39,35,34,33,42,52,56,55,53,63,61,65,64,59,60,47,51,50,40,44.
27 Sept. - 7,9,11,8,10,12,23,43,32,35,34,33,42,52,56,63,61,65,66,62.
2 Oct. - 7,6,3,5,2,1,12,13,14,35,34,33,42,46,52,56,63,61,65,58,57,64,54,49,48,41,38.
3 Oct. - 25,24,27,29,28,32,36,39,23,22,19,18.
5 Oct. - 33,34,35,42,52,56,63,61,65,66.
6 Oct. - 7,10,12,35,34,33,42,52,56,63,61,65,27.
11 Oct. - 23,22,21,19,18,17,16,15,45,24,43,25,27,30,31,32,38,39,37,35,34,33,42,47,51,50,44,40,23.
12 Oct. - 9,11,8,10,12,6,7,4,1,53,55,56,52,65,66,63,61,64,59,62,60.
18 Oct. - 56,52,63,61,65,66,58,62,57,54,48,4,5,3,6,7,8,10,12,20,13,14,17,19,18,22.
19 Oct. - 23,26,29,28,32,38,36,39,49,46,41,33.
20 Oct. - 43,35,34,42,52,24,27.
24 Oct. - 56,42,47,51,52,63,61,65,66,64,62,59,60,53,55,50,40,44,37,39,35,33,34.
25 Oct. - 6,7,4,2,9,10,12,8,11,16,15,17,18,21,45,23.
26 Oct. - 30,27,25,43,31,32,38.
30 Oct. - 35,34,33,36,51,42,46,49,48,52,56,63,61,65,66,62,58,57,54,41,38,32,43,24,26,28,29,27.
31 Oct. - 20,8,10,12,11,6,7,3,5,2,1,13,14,17,19,18,22,23.
6 Nov. - 37,39,35,34,33,38,1,2,3,4,7,9,20,11,8,16,15,18,19,45,23.
7 Nov. - 26,25,27,29,30,50,56,53,55,62,60,59,64,65,63,61.
8 Nov. - 42,52.
13 Nov. - 1,2,5,6,7,10,12,17,21,22,24,43,27,36,40,44,39.
14 Nov. - 35,42,46,52,56,65,66,63,61.

Table 7 Ross James Mortality Search Dates and Turbines Searched on each Day, 2007

21 Aug – 45,21,17,16,15.
22 Aug – 23,22,18,13,9,8,10,7,6,2,1,5,3,4,11,12,20,14,19.
23 Aug – 43,25,27,30,36,39,35,34,33,37,40,44,38,32,28,29,26,24,7.
24 Aug – 31,41,47,49,50,55,56,42,46,48,51,53,57,60,64,52.
25 Aug – 54,62,59,58,66,65,63,61,52.
28 Aug – 30,27,43,25,36,39,35,34,33,1,2,5,3,4,6,7,11,20,12,14,45.
29 Aug – 23,22,18,13,9,8,10,7,16,15,17,19,21,24,26,26,29,32,38,37.
30 Aug – 31,41,47,49,50,55,56,42,46,63,64,60,57,53,51,48,40,44.
31 Aug – 54,62,59,58,66,65,61,52.
4 Sept – 31,41,50,47,49,55,56,42,16,15,14,11,20,12,1,2,5,3,4,6,53.
5 Sept – 23,22,18,13,9,8,10,7,17,19,21,45,24,26,28,29,32,38,37,33,42.
6 Sept – 43,25,27,30,36,39,35,34,46,48,51,53,57,60,64,63,42.
7 Sept – 54,62,59,58,66,65,61,52.
11 Sept – 54,62,59,58,66,65,61,52,1,2,5,3,4,6,11,20,12,14,16,15,17,19,21.
12 Sept – 43,25,27,30,36,39,35,34,35,24,26,28,29,32,38,37,33,46.
13 Sept – 23,22,18,13,9,8,10,7,40,44,48,51,53,57,60,64,63.
14 Sept – 31,41,47,49,50,55,56,42.
15 Sept – 45,52.
17 Sept – 52,62,58,63,9.
18 Sept – 23,22,18,19,13,9,10,18,7,6,2,1,5,3,4,11,20,12,14,16,15,17,19,23,45.
19 Sept – 43,25,27,30,36,39,35,34,33,37,38,32,28,29,26,24.
20 Sept – 31,41,47,48,49,50,55,42,46,63,64,57,51,40,44.
21 Sept – 54,62,59,58,66,65,61,52.
25 Sept – 27,30,25,43,36,39,35,34,33,2,1,5,3,4,6,11,20,12,14,16,15,17,19,21,45.
26 Sept – 31,41,47,49,50,55,56,42,46,40,44,37,38,32,24,26,28,29.
27 Sept – 54,62,59,58,66,65,61,52,63,64,60,57,53,51,48.
28 Sept – 23,22,18,13,9,8,10,7.
2 Oct – 31,41,47,49,50,55,56,42,46,2,1,5,3,4,6,11,20,12,14,16,15,17,19,21,45.
3 Oct – 54,62,59,58,66,65,61,52,63,64,60,57,53,48,40,44,38,32,24.
4 Oct – 23,22,18,13,9,8,10,7,42,51,33,26,28,29.
5 Oct – 27,30,25,43,36,39,35,34.
9 Oct –54,62,59,58,66,65,61,52,63,64,60,57,53,51,48,46,40,44,37,36,38,32,24,26,28,29,27.
10 Oct – 23,22,18,13,9,8,10,7,6,4,3,1,2,5,11,20,12,14,16,15,17,19,21,45.
11 Oct – 27,30,25,43,36,39,35,34,33.
12 Oct – 31,41,47,49,50,55,56,42,
13 Oct – 7,4.
16 Oct – 23,22,18,13,9,8,10,7,2,3,1,5,3,4,11,12,14,20,16,15,17,19,21,45,24,26,28,29.
17 Oct – 27,30,25,43,36,39,35,34,33,46,48,51,63,64,60,57,53,40,44,37,38,32.
18 Oct – 31,41,47,49,50,55,56,42.
19 Oct – 54,62,59,58,66,65,61,52.
23 Oct - 27,30,25,43,36,39,35,34,33,45,21,17,16,15,14,11,20,12,6,4,3,5,2,1,19.
24 Oct – 31,41,47,49,50,55,56,42,46,63,64,60,57,53,51,48,40,44,37,38,32,24,26,28,29.
25 Oct – 54,58,59,62,66,65,61,52.
26 Oct – 23,22,18,13,9,8,10,7.
30 Oct – 31,41,47,49,50,55,56,42,46,26,28,29,45,21,19,17,16,17,14,11,12,4,3,1,2,5,6,20.
31 Oct – 54,62,59,58,66,65,61,52,63,64,60,57,53,51,48,40,44,37,33,38,32,24.
1 Nov – 23,22,18,13,9,8,10,7,6.
2 Nov – 27,30,25,43,36,39,35,34,35.
5 Nov – 64,60,57,53,51,48,44,40,37.
6 Nov – 31,41,50,54,62,59,58,66,65,63,52,46,33,38,32,24,26,28,29,45,21,19,17.
7 Nov – 25,27,30,23,22,18,19,13,9,8,10,7,6,4,3,5,1,2,20,12,11,16,15.
8 Nov – 43,36,39,35,34,42,49,47,55,56,52.

Table 8 Kevin Dance Mortality Search Dates with Turbines Searched, ’06 & ’07

		2006												2007											
		Turbine Number												Turbine Number											
Date		**T6**	**T7**	**T8**	**T10**	**T11**	**T12**	**T42**	**T47**	**T48**	**T52**	**T61**	**T63**	**T6**	**T7**	**T8**	**T10**	**T11**	**T12**	**T42**	**T47**	**T48**	**T52**	**T61**	**T63**
August	22-Aug																			x			x	x	x
September	5-Sep															x	x	x	x						
	8-Sep																				x	x	x		
	11-Sep																							x	x
	12-Sep																			x			x		
	14-Sep																				x	x	x		
	16-Sep																								x
	18-Sep								x	x	x	x	x												
	19-Sep	x	x			x		x												x					
	21-Sep																			x	x	x	x	x	x
	22-Sep																				x	x			
	24-Sep								x	x		x	x												
	25-Sep			x	x	x	x																	x	x
	26-Sep											x	x			x	x	x	x						
	27-Sep							x	x	x															
October	2-Oct			x																			x		
	3-Oct																			x					
	4-Oct																			x	x	x	x	x	x
	6-Oct															x	x	x	x						
	8-Oct			x	x		x				x														
	9-Oct								x	x		x	x												
	10-Oct																						x		
	11-Oct													x						x					
	12-Oct													x	x					x		x	x	x	x
	13-Oct																								
	14-Oct													x	x	x	x	x	x						
	15-Oct			x	x		x	x													x	x		x	x
	16-Oct							x	x	x											x	x	x		
	17-Oct													x	x	x	x	x	x						

	19-Oct																			x	x	x	x	x	x
	20-Oct																						x		
	22-Oct													x	x										
	24-Oct																			x	x	x			
	25-Oct																				x	x		x	x
	26-Oct													x	x	x	x	x	x						
	27-Oct																								
	28-Oct																						x		
	29-Oct													x	x										
	30-Oct			x	x	x		x	x	x											x	x		x	x
	31-Oct															x	x	x	x		x	x	x	x	x
November	1-Nov																				x	x	x		
	2-Nov													x	x	x	x	x	x						
	6-Nov								x	x		x	x												
	7-Nov													x	x	x	x	x	x						
	10-Nov																			x	x	x	x		
	12-Nov							x																	
	13-Nov	x	x											x	x	x	x	x	x						
	14-Nov											x	x												
	15-Nov																				x	x		x	x
	16-Nov																						x		
	18-Nov													x	x										
	19-Nov																				x	x	x		
	20-Nov																			x				x	x
	23-Nov								x	x															
	24-Nov																							x	x
	25-Nov										x													x	x
	26-Nov								x	x															
	27-Nov															x	x	x	x						
	28-Nov																				x	x	x		
	29-Nov													x	x	x	x	x	x	x	x	x	x	x	x
December	4-Dec										x														

Table 9 Summary Details of Scavenger Removal Trials During ’06 & ’07

2006

Date	Number of Scavenger Birds	Total Number for the Month	Percent of all Scavenger Birds for the Month (%)
Aug-23	12	12	12%
Sep-06	12	38	37%
Sep-12	12		
Sep-27	14		
Oct-03	9	33	32%
Oct-06	1		
Oct-18	21		
Oct-31	2		
Nov-07	19	19	19%
Total Number of Scavenger Birds		**102**	

2007

Date	Number of Scavenger Birds	Total Number for the Month	Percent of all Scavenger Birds for the Month (%)
Aug-21	6	12	19%
Aug-27	6		
Sep-03	6	25	39%
Sep-10	6		
Sep-17	6		
Sep-24	6 (+1 fresh kill)		
Oct-01	6	27	42%
Oct-08	6 (+1 fresh kill)		
Oct-15	6 (+2 fresh kill)		
Oct-22	6		
Total Number of Scavenger Birds		**64**	

Table 10 Break Down of Raptor Observations where Raptors were in the Risk Zone of within 0-40m out from a Turbine and at Blade Sweep Height, 2006 & 2007

	2006		2007		2006 & 2007 Combined	
	Percent of Total Observations (%)	Number of Observations	Percent of Total Observations (%)	Number of Observations	Percent of all Observations (%)	Total Number of Observations
Raptor Moved Parallel to Turbine	62	38	32	31	43	69
Passed turbine when blade orientation was partially perpendicular to the path of the bird	16	10	29	28	24	38
Raptor Moved Perpendicular to Turbine	5	3	6	6	6	9
Raptor Moved Perpendicular to Turbine then Avoided Blades	8	5	9	9	9	14
Near Collision Event but Flight Abilities Prevented Fatality	8	5	15	15	13	20
Turbine was not Operational	0	0	9	9	6	9
Total Number of Observations		**61**		**98**		**159**

Table 11 Raptor Mortality Rates at Wind Facilities in the United States, Canada, and Spain by Fatalities per Turbine and by MW per Year

Wind Project Name	Number of Turbines	MW per Turbine	Total MW for Facility	Raptor Mortality: Number Fatalities/Turbine/Year	Raptor Mortality: Number of Fatalities/MW/Year	Raptor Mortality: Estimated Number of Fatalities/Year	References
United States							
Stateline, OR/WA	454	0.66	300	0.06	0.09	27.24	Erickson *et al.* 2004
Vansycle, OR	38	0.66	25	0	0	0	Erickson *et al.* 2000
Klondike, OR	16	1.5	24	0	0	0	Johnson *et al.* 2003b
Nine Canyon, WA	37	1.3	48	0.07	0.05	2.59	Erickson *et al.* 2003b
Foote Creek Rim, WY Phase I	72	0.6	43	0.03	0.05	2.16	Young *et al.* 2001
Foote Creek Rim, WY Phase II	33	0.75	25	0.04	0.06	1.32	Young *et al.* 2003
Wisconsin, WI	31	0.66	20	0	0	0	Howe *et al.* 2002
Buffalo Ridge, MN Phase I	73	0.3	22	0.01	0.04	1.43	Johnson *et al.* 2002
Buffalo Ridge, MN Phase I	143	0.75	107	0	0	0	Johnson *et al.* 2002
Buffalo Ridge, MN Phase II	139	0.75	104	0	0	0	Johnson *et al.* 2002
Top of Iowa	89	0.9	80	0.01	0.01	0.89	Koford *et al.* 2004
Buffalo Mountain, TN	3	0.66	2	0	0	0	Nicholson 2003
Mountaineer, WV	44	1.5	66	0.03	0.02	1.32	Kerns & Kerlinger 2004
Altamont Pass Wind Resource Area, CA	**5400**	**40 to 400 kW**	**580**	**Not available**	**0.75 (Unadjusted); 1.9 (adjusted)**	**434 (unadjusted); 1,127 up to 2,277 (adjusted)**	**Smallwood & Thelander 2007**
Canada						0	
Erie Shores, ON (2006 & 2007)	**66**	**1.5**	**99**	**0.042 to 0.073**	**0.028 to 0.049**	**2.8 to 4.79**	
Wolfe Island Wind Farm (2009-2010)	86	2.3	197.8	0.27	0.12	5.82	Stantec Consulting Ltd. 2010
Melancthon, ON Phase I (2006)	45	1.5	68	0.02	0.013	0.9	Stantec Consulting Ltd. 2007
Melancthon, ON Phase I (2007)	45	1.5	68	0.07	0.047	3.15	Stantec Consulting Ltd. 2007
Europe							
SmolaWind Farm	**68**	**2 to 2.3**	**150**	**No mortality rates calculated but 10 White-tailed sea eagle fatalities found from August 2005 to March 2007**			**Follstad 2007**
Tarifa, Spain (2004) E3	**16**	**180 kW**	**2880**	**0.03**	**0.19***	**12.54***	**Barrios & Rodriguez 2004**
	50	**150kW**	**7500**				
PESUR	**155**	**100kW**	**15500**	**0.36**	**3.3***	**627***	**Barrios & Rodriguez 2004**
	35	**150kW**	**5250**				
Tarifa, Spain (2008) E3	**16**	**180 kW**	**2880**	**0.0407**	**0.259***	**26**	**de Lucas *et al.* 2008**
	50	**150 KW**	**7500**				
PESUR	**156**	**100 kW**	**15600**	**0.068**	**0.624***	**125**	**de Lucas *et al.* 2008**
	34	**150 kW**	**5100**				

* = The values for the number of fatalities/MW/year were estimated by averaging the number of MW/turbine for all turbine types in each facility to provide an estimate of mortality per MW produced

Table 12 Raptor Flight Height Comparison at Proposed Wind Farm Locations and Existing Wind Farms

Species	Wind Farm	Number of Observations	Flight Height *	Percent of Observations (%)	Type of Study
Buteos					
Buteos	Foote Creek Rim, Wyoming[a] (BH=25-125m)	1047	ABH	19.7	Pre-construction
			BH	35.9	
			UBH	44.4	
Red-tailed Hawk	Dairy Hills, New York[b] (BH=25-125m)	19	ABH	15.79	Pre-construction
			BH	68.42	
			UBH	15.7	
	Maiden Wind Farm, Oregon[c] (BH=25-125m)	29	ABH	31.03	Pre-construction
			BH	58.62	
			UBH	10.34	
	Buffalo Ridge Phase I[d] (BH=21-51m)	Un	BH	30	Post-construction
	Altamont, California[e] (BH= 14-34m)	Un	BH	5x more frequently at 11-50m above ground than any other height level	Post-construction
Rough-legged Hawk	Dairy Hills, New York[b]	3	ABH	0	Pre-construction
			BH	66.67	
			UBH	33.33	
Ferrugenous Hawk	Maiden Wind Farm, Oregon[c]	6	ABH	0	Pre-construction
			BH	50	
			UBH	50	
Swainson's Hawk	Maiden Wind Farm, Oregon[c]	26	ABH	23.08	Pre-construction
			BH	73.08	
			UBH	3.85	
	Buffalo Ridge Phase I[d]	Un	BH	20	Post-construction

Eagles					
Eagle sp.	Foote Creek Rim, Wyoming[a]	1163	ABH	32.2	Pre-construction
			BH	42.4	
			UBH	25.4	
Golden Eagle	Maiden Wind Farm, Oregon[c]	6	ABH	66.67	Pre-construction
			BH	33.33	
			UBH	0	
White-bellied Sea Eagle	4 wind farms in Australia[f] (BH= 30-120m)	160	BH	70	Post-construction
			UBH	30	
Northern Harrier	Maiden Wind Farm, Oregon[c]	50	ABH	2	Pre-construction
			BH	20	
			UBH	78	
	Dairy Hills, New York[b]	4	BH	25	Pre-construction
			UBH	75	
	Based on 8 proposed or existing wind farms data[g]	Un	UBH (for all facilities)	50-80	Pre-construction & Post-construction
Falcons					
Large Falcons	Foote Creek Rim, Wyoming[a]	154	ABH	18.3	Pre-construction
			BH	33.6	
			UBH	45.1	
Small Falcons	Foote Creek Rim, Wyoming[a]	291	ABH	6.1	Pre-construction
			BH	20.8	
			UBH	73.1	
American Kestrel	Maiden Wind Farm, Oregon[c]	25	ABH	4	Pre-construction
			BH	16	
			UBH	80	
	Buffalo Ridge Phase I[d]	Un	BH	30	Post-construction
	Dairy Hills, New York[b]	2	UBH	100	Pre-construction
Prairrie Falcon	Maiden Wind Farm, Oregon[c]	9	ABH	11.11	Pre-construction
			BH	88.89	
			UBH	0	
Peregrine Falcon	Maiden Wind Farm, Oregon[c]	2	BH	100	Pre-construction

Accipiters					
Accipiters			ABH	10.7	
	Foote Creek Rim, Wyoming[a]	62	BH	62.5	Pre-construction
			UBH	26.8	
Sharp-shinned Hawk	Dairy Hills, New York[b]	1	ABH	100	Pre-construction
	Maiden Wind Farm, Oregon[c]	1	BH	100	Pre-construction
Cooper's Hawk			ABH	25	
	Maiden Wind Farm, Oregon[c]	4	BH	50	Pre-construction
			UBH	25	
Vultures					
Turkey Vulture			ABH	20.97	
	Dairy Hills, New York[b]	62	BH	72.58	Pre-construction
			UBH	6.45	
All Raptors					
All Raptors (14			ABH	3.6	
	Foote Creek Rim, Wyoming[a]	223	BH	45	Pre-construction
			UBH	51.4	
All Raptors (11			ABH	18.36	
	Maiden Wind Farm, Oregon[c]	207	BH	48.31	Pre-construction
			UBH	33.33	
All Raptors (3 Species)	Buffalo Ridge Phase I[d]	266	BH	20-31	Post-construction
All Raptors (15			ABH	50.8	
	Erie Shores Wind Farm (BH= 41.5-118.5)	6,631	BH	27.2	Post-construction
			UBH	22	

* = Flight heights (ABH= Above Blade Sweep Height; BH= Blade Sweep Height; UBH =Under Blade Sweep Height)
Un = Unknown number of observations
[a] =Western EcoSystems Technology Inc. 2000; [b] = West Inc. 2005; [c] = Western EcoSystems Technology Inc & Northwest Wildlife Consultants Inc. 2002; [d] = Osborn *et al.* 1998; [e] = Hoover & Morrison 2005; [f] = Smales 2005; [g] = Whitfield & Madders 2006

Illustration 1. GE Model 1.5 sle Wind Turbine Diagram

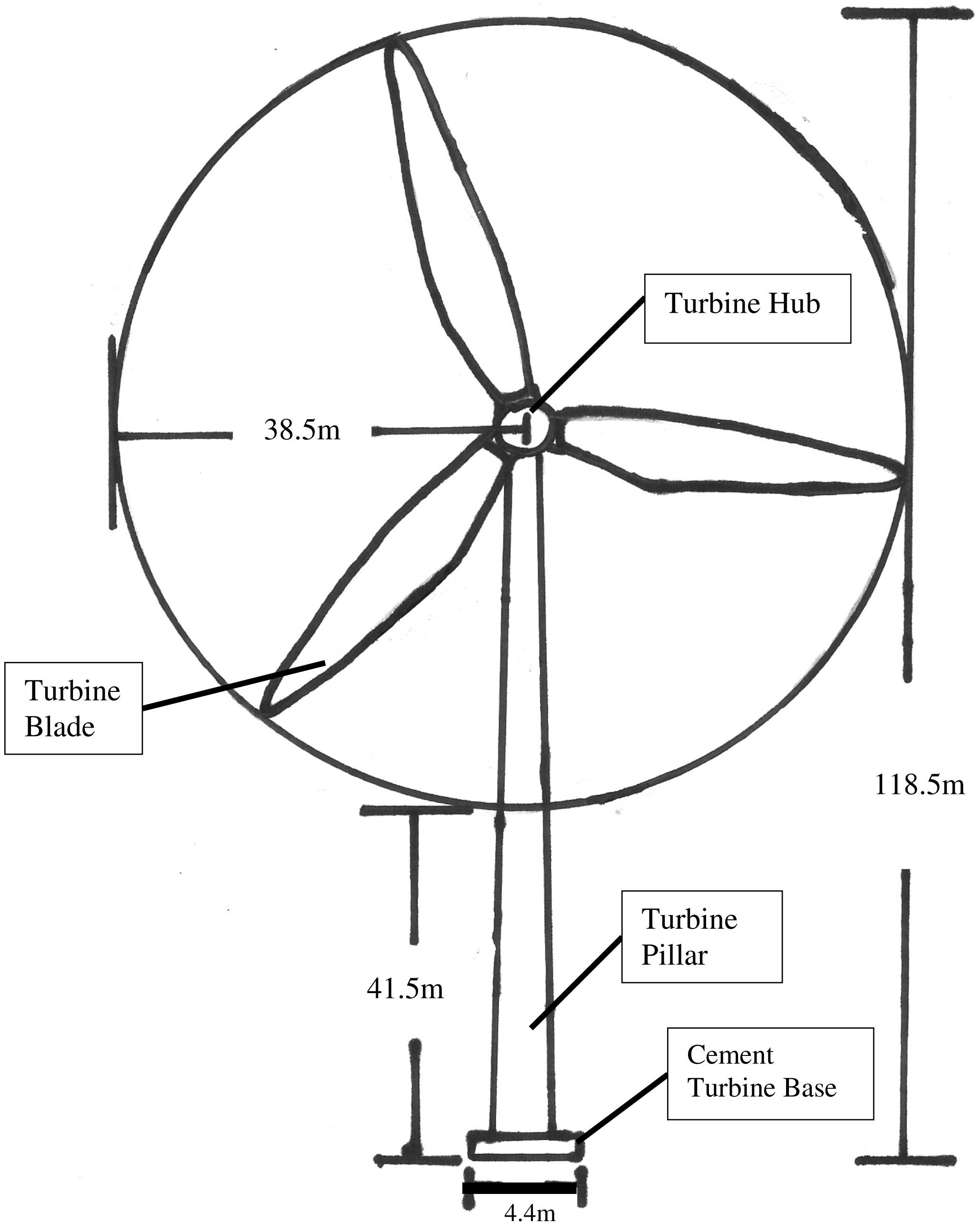


Illustration 2. Mortality Search Method Diagram

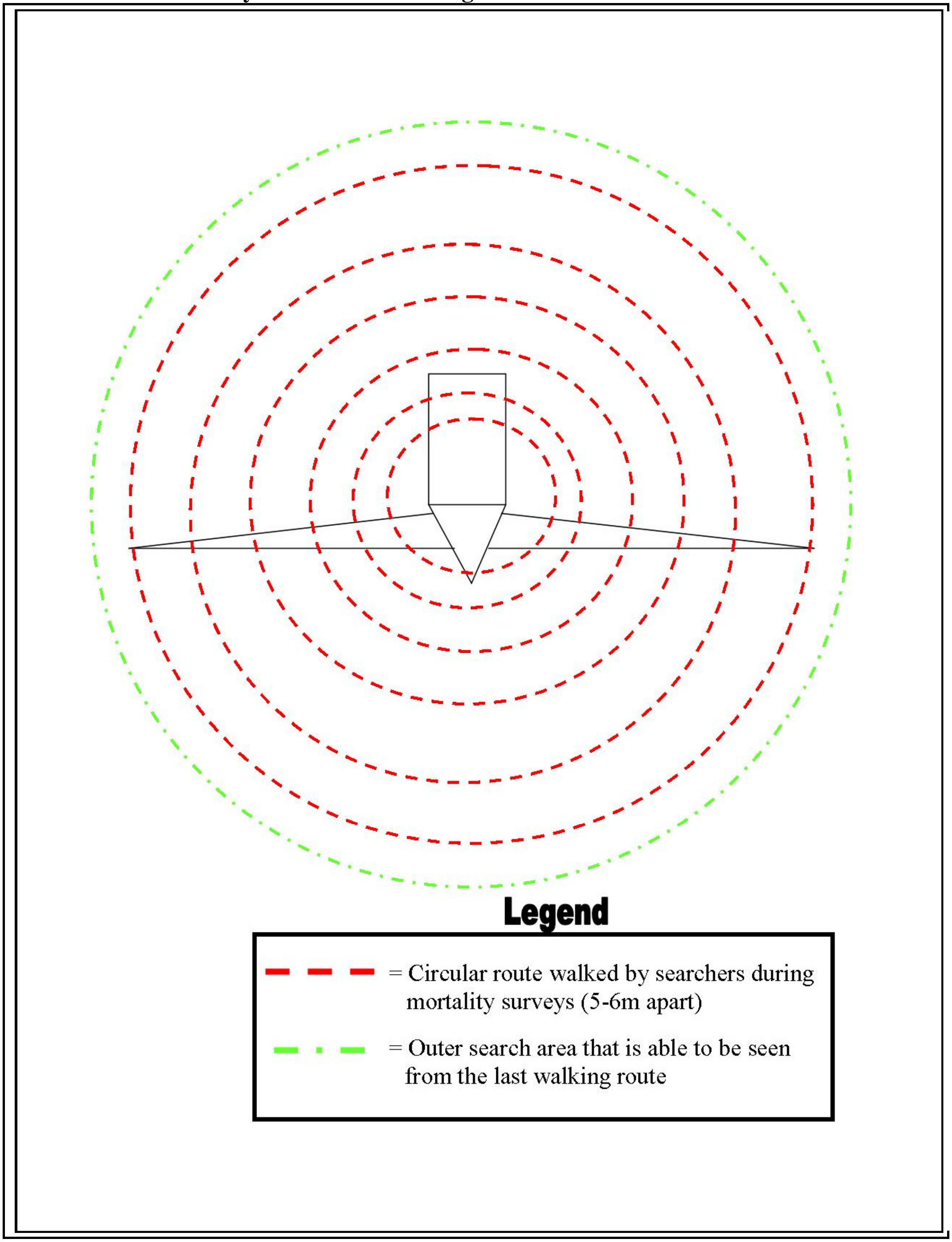


Illustration 3. Photos of Sharp-shinned Hawk Fatality, 2006

Sharp-shinned Hawk Fatality, September 26th, 2006

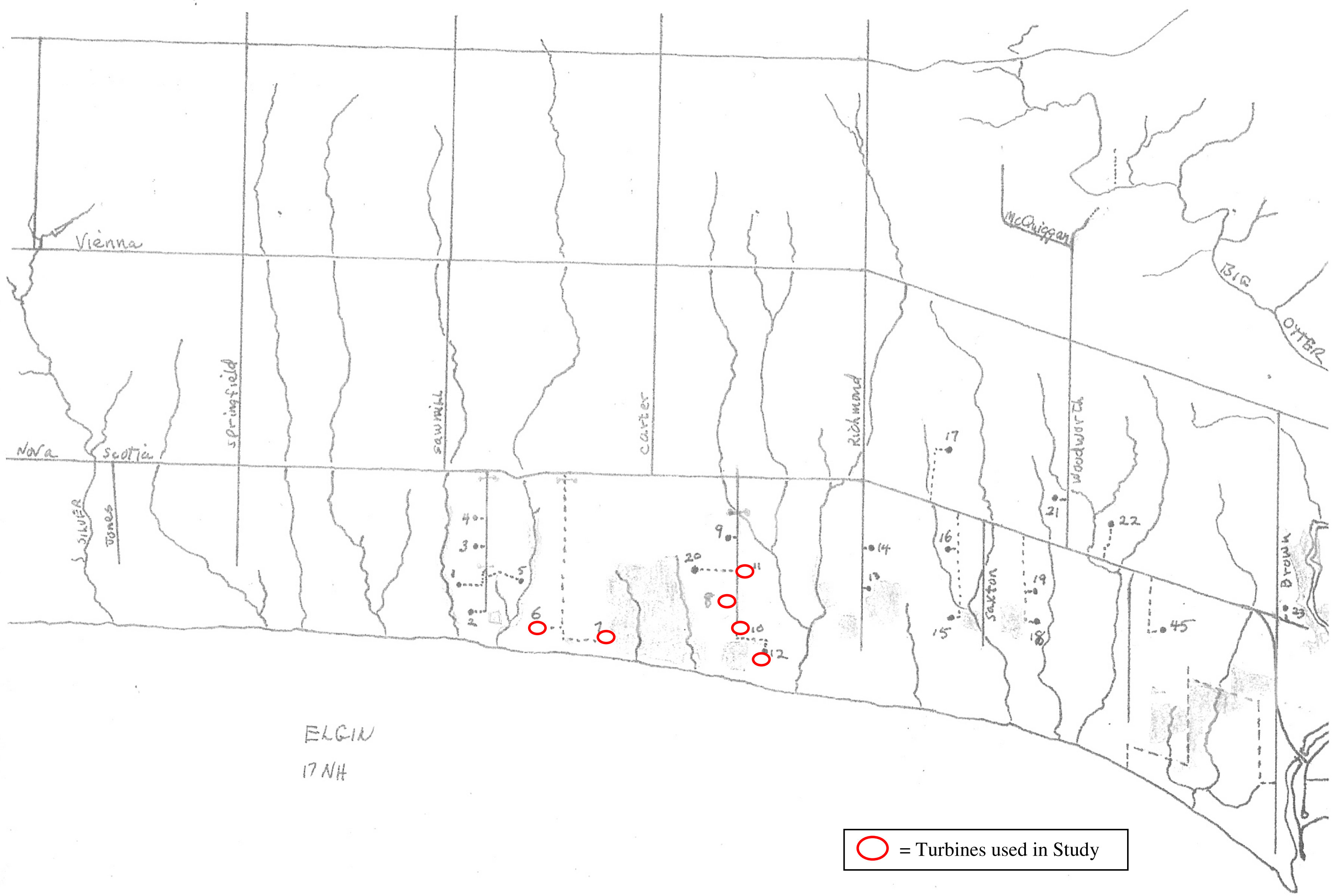
Sharp-shinned Hawk Fatality in Relation to Wind Turbine

Illustration 4. Photos of Red-tailed Hawk Fatality, 2007

Red-tailed Hawk Fatality November 29th, 2007

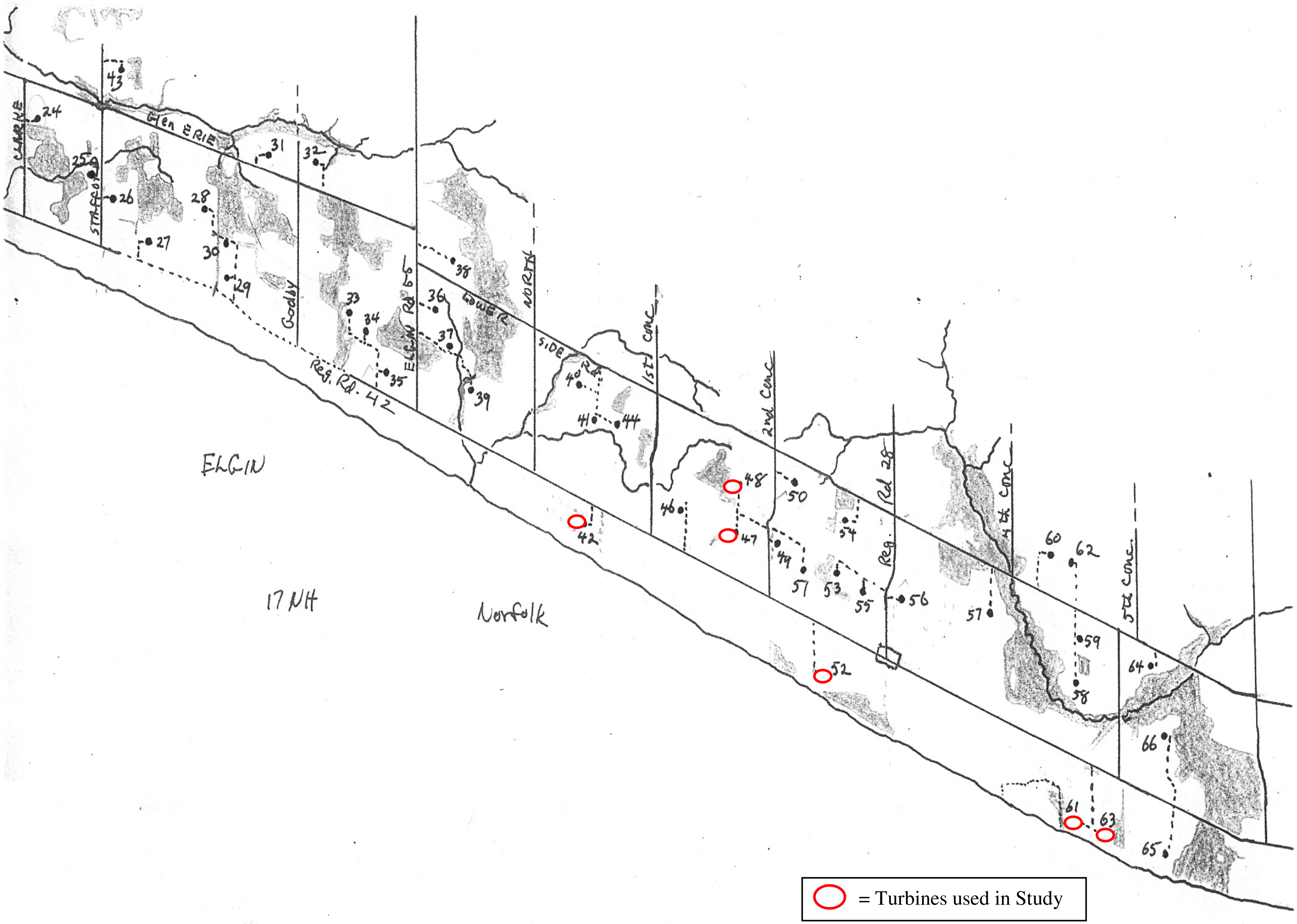
Red-tailed Hawk Fatality in Relation to Nearest Turbine

Map 1. Erie Shores Wind Farm, West of Port Burwell



Map courtesy of James, R (2006)

Map 2. Erie Shores Wind Farm, East of Port Burwell



Map courtesy of James, R (2006)

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