Estimating Trumpeter Swan (*Cygnus buccinator*) Populations in Alberta and Response to Disturbance

by

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Abstract

Trumpeter Swans (*Cygnus buccinator*) were once widespread across much of North America, but after years of exploitation were reduced to near extinction. This research addressed the extent that human disturbance is affecting Trumpeter Swan breeding productivity and developed a more efficient survey method for populations in Alberta. Disturbance experiments were conducted using a pedestrian to determine the range a disturbance response is elicited. The relationship between swan breeding productivity and distances to landscape human features around nesting lakes was examined using linear regressions. Trumpeter Swans had a maximum escape distance of 1179 m and an average escape distance of 736±46 m (n=19). Disturbance models involving well sites (p=0.033), power lines (p=0.004), and cut lines (p=0.032) in 2010 were significant. Stratified Random Sampling accurately estimated Trumpeter Swan populations in 2000 and 2005 using strata of 0, 1-50, 51-100, and 101+ swans per survey block.

Preface

This thesis is an original work by Jerrod Looft. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Animal Care and Use Committee for Biosciences, "Trumpeter Swan Population Recovery in Alberta, Land Use and Response to Disturbance", No. 7351005, May 3rd, 2010 and No. 7350412, May 1st, 2011. This project received a permit for working with migratory birds from the Environment Canada, Canadian Wildlife Service, No. 11-AB-SC022, June 6th, 2010. A research and collection permit was issued by Alberta Tourism, Parks and Recreation, "Examining Trumpeter Swan Productivity and population in Alberta; survey methods and swan response to disturbance," No. 11-078, May 20th, 2011. A collection license was acquired from Alberta Sustainable Resource and Development, Fish and Wildlife Division, No. 27853 and No. 27824, May 1st, 2011.

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1 Background of Trumpeter Swans

1.1 Trumpeter Swan Ecology

Trumpeter Swans (Figure 1.1) are the largest species of waterfowl in North America with an average weight of 12 kg for males and 10 kg for females (Bellrose 1976, Mitchell 1994). As an adult, these birds are all white except for their black bills and feet. This makes them easily distinguishable from every other waterfowl in North America except for the Tundra Swan (*Cygnus columbianus*). In the field these two birds resemble each other with Trumpeters tending to be larger and Tundras usually having a yellow spot in front of the eye. Vocalizations are a much better way of distinguishing between the two, with the Trumpeter having a low, horn-like call and the Tundra having a quavering high pitched call (Bellrose 1976). While often impractical, for best identification between the two species one would have to conduct a dissection in which the Trumpeter would easily be identified by a loop in its windpipe over a bony hump on the sternum.

Figure 1.1 – Trumpeter Swan on Kamisak Lake in Alberta.

Trumpeter Swans are divided into three distinct breeding populations: Pacific Coast, Rocky Mountain, and Interior populations (Figure 1.2). The Pacific Coast population is the largest with an estimated 26,760 birds in 2010 (Groves 2012). The majority of this population nests in Alaska with smaller groups nesting in Yukon and northwestern British Columbia. The Interior population is the second largest population with approximately 9,809 birds in 2010 (Groves 2012). This population has a wide range extending from Saskatchewan through Ontario and eastward into New York and a southern subpopulation across much of Colorado (Fig 1.2). The Rocky Mountain population had an estimated 9,600 birds in 2010 (Groves 2012). This population is divided into two portions. The majority of the population breeds in Alberta, British Columbia, Northwest Territories, and the Yukon, and then winters in the

Tri-state area of Montana, Idaho, and Wyoming. The second portion breeds and winters in the United States, mainly in the Tri-state area. This study will focus on the Rocky Mountain population nesting in Alberta mainly because of funding reasons. The Grande Prairie area was chosen for field work because of the high density of nesting swans in the area made it more efficient for field work. Also swans have been using this area for longer than anywhere else in Alberta and there have been records of swan surveys for this area dating back to the 1940's.

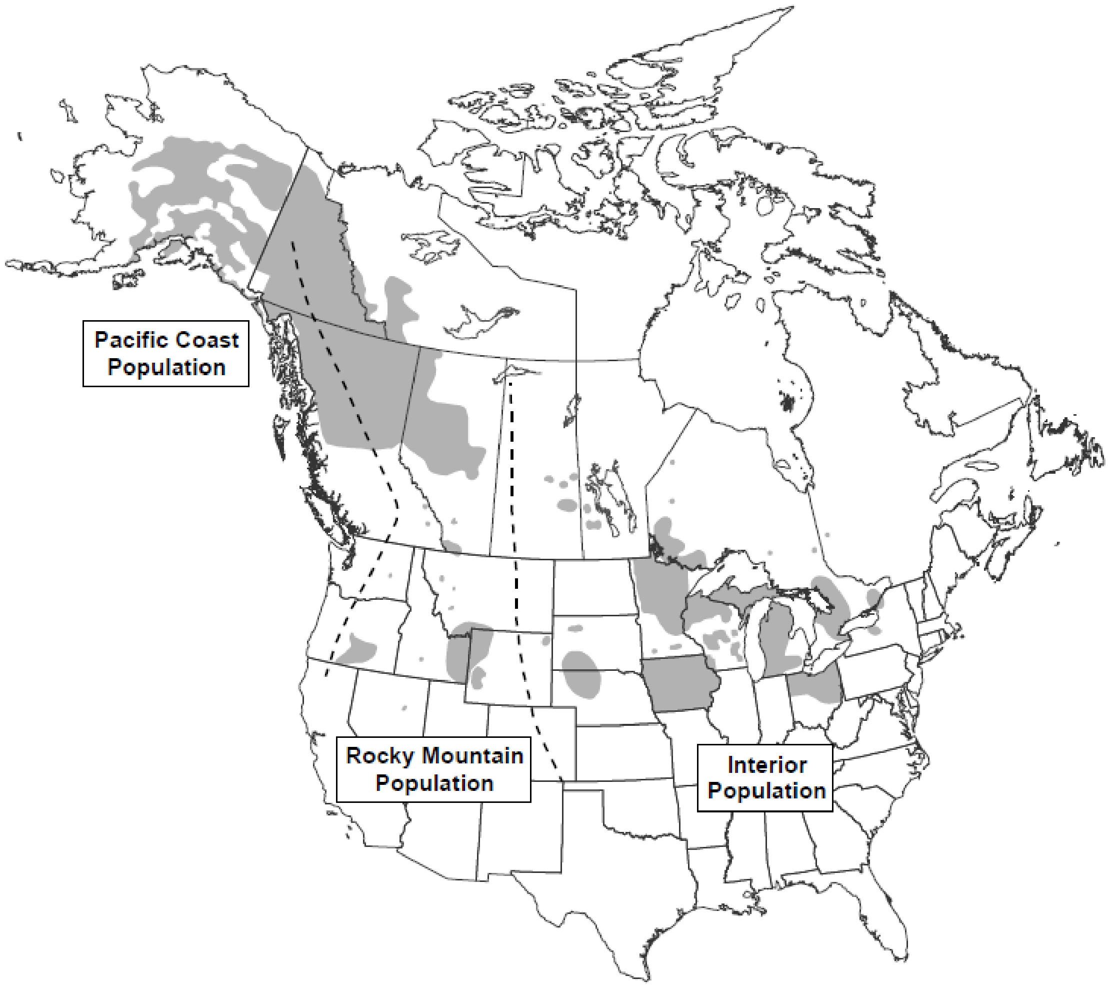

Figure 1.2- The breeding range of the three Trumpeter Swan populations (Groves 2012).

Trumpeter Swans are long-lived birds and individuals in the wild are known to reach at least 24 years of age (Mitchell 1994). Trumpeters mate for life and pair formation begins as early as two years of age, although first breeding attempts usually do not begin until 4-7 years of age (Banko 1960, Mitchell 1994). Nests are initiated in mid-April to early May in Alberta depending on weather and ice conditions. Usually only one pair will occupy a nesting lake unless it is large and provides visual/spatial isolation. High site fidelity and territorial defense is exhibited by pairs between years (Mitchell 1994). Nests are usually built on muskrat (*Ondatra zibethicus)* or beaver (*Castor canadensis*) lodges, islands, or in either floating mats or stands of emergent vegetation. Both members of the pair contribute to nest construction during which the vegetation surrounding the nest is uprooted and placed on the mound, forming a nest approximately 2-3 meters in diameter (Figure 1.3) (Banko 1960). Typical nesting materials in the Grande Prairie region consisted of cattails (*Typha spp.*) and bulrushes (*Scirpus spp.*) (James 2000 and personal observation). Clutches vary in size from 1-9 eggs and incubation lasts for 32-37 days (Banko 1960, Mitchell 1994). Hatching occurs in late May through June. Hatching success varies but is often low with estimates of 51-66% of eggs hatching (Banko 1960). Once hatching occurs, fledging follows in 90-120 days if habitat is adequate (Banko 1960, Mitchell 1994). After fledging, the family groups typically stay together through the southern portion of the migration and the juveniles may even follow parents back to the breeding grounds. Dispersal of juvenile swans after their return to the breeding grounds has not been thoroughly documented, but numerous non-breeding flocks presumed to be pre-breeding or non-territorial immature birds are observed in the

Grande Prairie region each year.

Figure 1.3 – Trumpeter swan nest made of cattails on a floating organic mat.

Adult Trumpeter Swans feed almost exclusively on plant matter. Trumpeters have been observed to consume up to 9 kg of aquatic vegetation per day (Page 1974). Important aquatic plants for Trumpeter Swans include the leaves, stems, roots and tubers of horsetail (*Equisetum spp*.), pondweeds (*Potamogeton spp*.), sedges (*Carex spp*.), as well as many other emergent and submersed plant species (Banko 1960, Holton 1982, and LaMontagne *et al.* 2003). Trumpeter Swans will generally feed in shallow water where their long necks allow them to reach submersed vegetation, and in some instances, they will tip up in a manner similar to puddle ducks for extra reach (Figure 1.4) (Banko 1960). During their first 2-5 weeks, cygnets feed almost exclusively on high protein invertebrate matter before switching to the vegetation diet of adults at 2-3 months of age (Banko 1960). This large intake of invertebrates initially and plant matter subsequently suggests the potential for food limitation of key nutrient-rich plant parts. Food limitations may explain the need for Trumpeter's territoriality on breeding lakes and the typical distribution of one family group per lake.

Figure 1.4 – Trumpeter Swans using their long necks to feed on submerged vegetation.

1.2 Recovery Questions

The Trumpeter Swan has been identified as a species of special concern in Alberta, and it is important to understand its ecology when setting recovery goals and objectives. The province of Alberta has created a set of recovery goals identifying population levels set for this species as well as factors hindering recovery goals and objectives. This species' limited breeding potential from late maturity, limited nesting attempts, and high sensitivity to human activities have all been highlighted as important management issues and potential barriers to trying to reach recovery goals. Trumpeter's have been observed to have negative reactions to human activities, especially while on nesting lakes, however the extent of this avoidance has not been thoroughly documented (Figure 1.5). In the first chapter questions involving the extent to which human activities may be affecting Trumpeter Swan breeding ecology including distance between the activity and swans and how it may affect their breeding potential are examined.

Figure 1.5 – A Trumpeter Swan using a lake in a residential area of Grande Prairie.

Once the recovery goals and objectives had been set for the population recovery, methods were needed to measure population growth and expansion to monitor recovery success. In the second chapter I delve into new survey methods to the continued monitoring of Trumpeter Swan populations. Aerial surveys have been used since the early 1950's to monitor Trumpeter swan populations in Alberta because of their ease of detection and large known area of occurrence due to high breeding lake territoriality. Starting in 1970 a continental breeding population survey of the Trumpeter Swan population has been conducted. From 1980 to 2005 the province of Alberta and the Canadian Wildlife Service have surveyed and calculated a Total Minimum Population estimate for Trumpeter Swans in Alberta by surveying known locations of swans in past surveys and close lakes likely to support swan expansion. In 2010 they were unable to do this because of the swan's large range of expansion and the lack of funding needed to cover this entire area. With these new survey constraints a method had to be used: stratified random sampling. In my second chapter I attempt to refine the strata needed in this survey method to make it accurate for use in Alberta.

1.3 References

Banko, W.E. 1960. The Trumpeter Swan. North American Fauna No. 63, U.S. Fish and Wildlife Service, Washington, DC.

Bellrose, F.C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

Groves, D.J. 2012. The 2010 North American trumpeter swan survey. U.S. Fish and Wildlife Service, Division of Migratory Bird Management, Juneau, Alaska, USA.

Holton, G. 1982. Habitat use by trumpeter swans in the Grande Prairie region of Alberta. Thesis, University of Calgary, Calgary, Canada.

James, M.L. 2000. Status of Trumpeter Swan (Cygnus buccinator) in Alberta. Alberta Environment, Fisheries and Wildlife Management Division, and Alberta Conservation Association, Wildlife Status Report No. 26, Edmonton, AB.

LaMontagne, J.M., L.J. Jackson, and R.M.R. Barclay. 2003. Characteristics of ponds used by trumpeter swans in a spring migration stopover area. *Canadian Journal of Zoology* 81: 1791-1798.

Mitchell, C.D. 1994. Trumpeter swan (*Cygnus buccinator*): The birds of North America. The Academy of Natural Sciences, Philadelphia, Pennsylvania, USA and The American Ornithologists' Union Number 105, Washington, D.C., USA.

Page, R.D. 1974. The ecology of the trumpeter swan on Red Rock Lakes National Wildlife Refuge, Montana. Final Report, U.S. Fish and Wildlife Service, Region 1.

2 Human Disturbance and its Effect on Productivity

2.1 INTRODUCTION

2.1.1 Trumpeter Swan Status in Alberta

In September 2001 the Trumpeter Swan was listed as a *Threatened* species in Alberta by the Minister of Sustainable Resources. The main reasons for listing this species was its small breeding population (<1000 birds), dependence of the breeding population on habitats vulnerable to human disturbance and concern over limited wintering habitat (Fish and Wildlife Division 2004). In response to this listing, several recovery plans have been developed by the Alberta Swan Recovery Team with the most recent being published in 2006. The recovery plan assessed limiting factors on Trumpeter Swan populations and gave recommendations for conserving and managing this species as well as acknowledging information gaps.

One of the main factors suspected of limiting Trumpeter Swan numbers, as outlined by the 2006 Alberta Recovery Plan, was human disturbance on breeding lakes. Many Trumpeter Swans have been shown to be highly sensitive to human disturbance while on their nesting lakes (Hensen and Grant 1991). If this disturbance causes the abandonment of nests or the loss of a clutch, the reproductive output for the year from that pair would be lost because Trumpeter Swans do not have sufficient time or resources to re-nest at this latitude (Banko

1960, Hensen and Grant 1991). This is why the recovery plan has recommended no human activity within 800 m of known swan nesting lakes during the breeding season, and no permanent development within 500 m. These distances were drawn from the best estimates of professional biologists yet no explicit data existed on this question.

2.1.2 Disturbance

There was a significant knowledge gap about the actual effects of human disturbance on Trumpeter Swans while on their breeding lakes (James 2000). Trumpeter Swans sometimes abandon their nests because of human disturbance (Banko 1960, Henson and Grant 1991) thus, the species is believed to be very sensitive to human activities during the pre- and early incubation period. Importantly, this assumption of sensitivity is drawn from natural history observations and not quantitative experiments. Banko (1960) proposed that Trumpeter Swans had an escape-flight distance of greater than 300 yards. Other species of swans, such as the Bewick's Swan (*Cygnus bewickii*), have been shown to have much shorter escape distances with an average of 160 m, which was the longest of the waterfowl species in the study area (Mori *et al*. 2001). Tundra Swans left nests to escape human disturbance at distances of 500-2000 m (Monda *et al*. 1994). Based on the similarity of these swan species with Trumpeter Swans, I predicted Trumpeter Swans would demonstrate similarly large escape distances from human disturbances.

Presumably, different types of anthropogenic disturbances will have different effects on swans. Henson and Grant (1991) found that aircraft, boats, vehicles, and pedestrians all affected breeding Trumpeter Swans. Louder vehicles, such as a low flying aircraft, airboats, or heavy construction vehicles caused disturbance reactions when normal vehicle traffic and normal flying aircraft did not illicit a noticeable reaction. Land forms and visual barriers separating nesting swans and roadways also decreased disturbance response to vehicle traffic. Pedestrians had a far greater disturbance effect on swans than any type of vehicular traffic. In a separate study Pease *et al*. (2005) also found that pedestrians caused greater disturbance to waterfowl than vehicle traffic. Management and protection of swan breeding sites must take into account swan responses to different disturbance stimuli. For example, results of these studies suggest that a shoreline hiking trail along a swan nesting lake may have greater negative effects than a road 200 m away with a tree-lined barrier.

Henson and Grant (1991) hypothesized that the reactions swans have to disturbance can increase nest predation and embryo mortality, cause retarded development in eggs due to exposure, and lead swans to avoid certain lakes. Risks of nest predation increase with disturbance because eggs were much more vulnerable to predation when unprotected by brooding parents. Leaving eggs unattended also means nests are more vulnerable to avian predators such as Common Ravens (*Corvus corax*) which predate swan eggs (Monda *et al.* 1994). A direct link exists between incubation continuity and incubation time with greater incubation constancy resulting in shorter incubation periods (Henson and Cooper 1993). Hatching as early as possible is important for swans in northern Alberta because cygnets must fledge and migrate before lakes freeze, typically in the latter half of October. Though scant, most of the work conducted on swan hatching success has been conducted on high-density swan nesting areas in the Tristate area, of Montana, Wyoming, and Idaho. Banko (1960) recorded low hatching success ranging from 51-66%.

Human disturbance can be directly measured by specific behavioral interactions but also the results of disturbance may be inferred from swan settling and nesting success patterns. Schmidt *et al*. (2009) provided one of the few studies of these disturbance patterns. They found that transportation infrastructure within 402 m to swan breeding lakes had a negative effect on lake occupancy by swans. Presence and number of oil wells actually showed a small positive relationship on lake occupancy, but few were in use during the study period. Numerous studies have shown similar types of negative effects with roads and occupancy of an area by other species of waterbirds (Burton *et al*. 2002a, Keller 1991, Klein *et al.* 1995, and Milsom *et al.* 1998). Waterbirds also avoid proximity of heavy construction areas and foot paths (Burton *et al*. 2002a and Burton *et al.* 2002b). With oil and gas exploration pressing into new and more remote areas of the publically owned northern reaches of Alberta (called the "green zone"), management guidance is called for to maintain high quality breeding lakes for swans.

There is some contradictory information however regarding human disturbance as a limitation on Trumpeter Swan breeding success; for example, there is a subpopulation of Trumpeter Swans in the Grande Prairie, Alberta area that appear to thrive in high human disturbance areas. These swans nest in a highly agricultural landscape with some even nesting on lakes surrounded by housing developments. While it is unclear why they are occupying these lakes, there are many possible explanations including the possibility of learned, imprinted or habituated behaviors of these long-lived birds. Habituation is the process of an organism either minimizing response or ceasing to respond to a stimulus due to repeat exposures of the stimulus without experiencing negative effects (Bourdeau 1968). Many other waterfowl species have been shown to habituate to some human activities (Conomy *et al.* 1998). Of particular note, other swan species have shown the ability to become habituated to human activities. Bewick's Swans in Europe have had to deal with higher human densities for a much longer time than Tundra swans, which are relatively undisturbed by humans in their high Arctic nesting areas and possibly as a result, Tundra Swans show a much larger average escape distance (Monda *et al*. 1994 and Mori *et al*. 2001). Trumpeter Swans nesting in high activity agricultural areas may also be using these lakes as a result of competition for nesting territories when all other water bodies in the area are occupied. The Grande Prairie area has the highest densities and greatest total population of Trumpeter Swans in Alberta (Alberta Trumpeter Swan Recovery Team 2006). A third theory for occupancy of suburban sites is the possibility that the abundance of food resources found in and around these very rich but highly disturbed lakes outweighs the negative effects of human disturbance. There may be other explanations or combinations of explanations for this incongruous behavior related to proclivities or individual swan "personalities" (Dingemanse *et al.* 2004).

2.1.3 Objectives and Hypotheses

The objective for this portion of the study is to examine the relationships between swan productivity and human disturbance surrounding their breeding lakes.

My null hypotheses are that there will be no significant difference in reproductive productivity between swans nesting in Green Zone vs. White Zone and distance of nesting lake to the nearest road, well site or petroleum infrastructure, cutline, pipeline, power line, and rail road.

2.2 METHODS

2.2.1 Study Area

The Smoky Wildlife Management Unit (Figure 1.3) is a designated area of land created by the Alberta Sustainable Resource and Development Fish and Wildlife Division for the purpose of wildlife management. It is located in west central Alberta and is bounded by British Colombia on the west, the Peace River on the North, by a mixture of the Little Smoky River and Township lines on the east, and a mixture of the Township lines, the Smoky River, and Wilmore Wilderness Park in the south. The Smoky Unit contains a variety of Natural Regions as defined by the Natural Regions Committee (2006) including Parkland Natural Region, Boreal Natural Region, Foothills Natural Region, and Rocky Mountain Natural Region. The Foothills Natural Region has rolling topography with many habitats including deciduous, mixed woods, and coniferous forests. The Parkland Natural Region contains both deciduous forests and willow shrub land habitats. The Boreal Forest Natural Region contains deciduous, mixed woods, and coniferous forests. This area has also been the subject of extensive human development. Much of the land near Grande Prairie has been cleared for agricultural purposes, mainly row crops in the Parkland Region, and hay and pasture in the Boreal and Foothill Regions. Forest harvesting is also prevalent in the Boreal and Foothill Regions and has been increasing recently in efforts to combat the spread of Mountain Pine Beetle (*Dendroctonus ponderosae*) infestations. Oil and gas extraction and their associated infrastructure (e.g. roads, well pads, compressor stations, pipelines, seismic lines, power lines, and helicopter pads) constitute the most widespread development affecting all Natural Regions in northern Alberta.

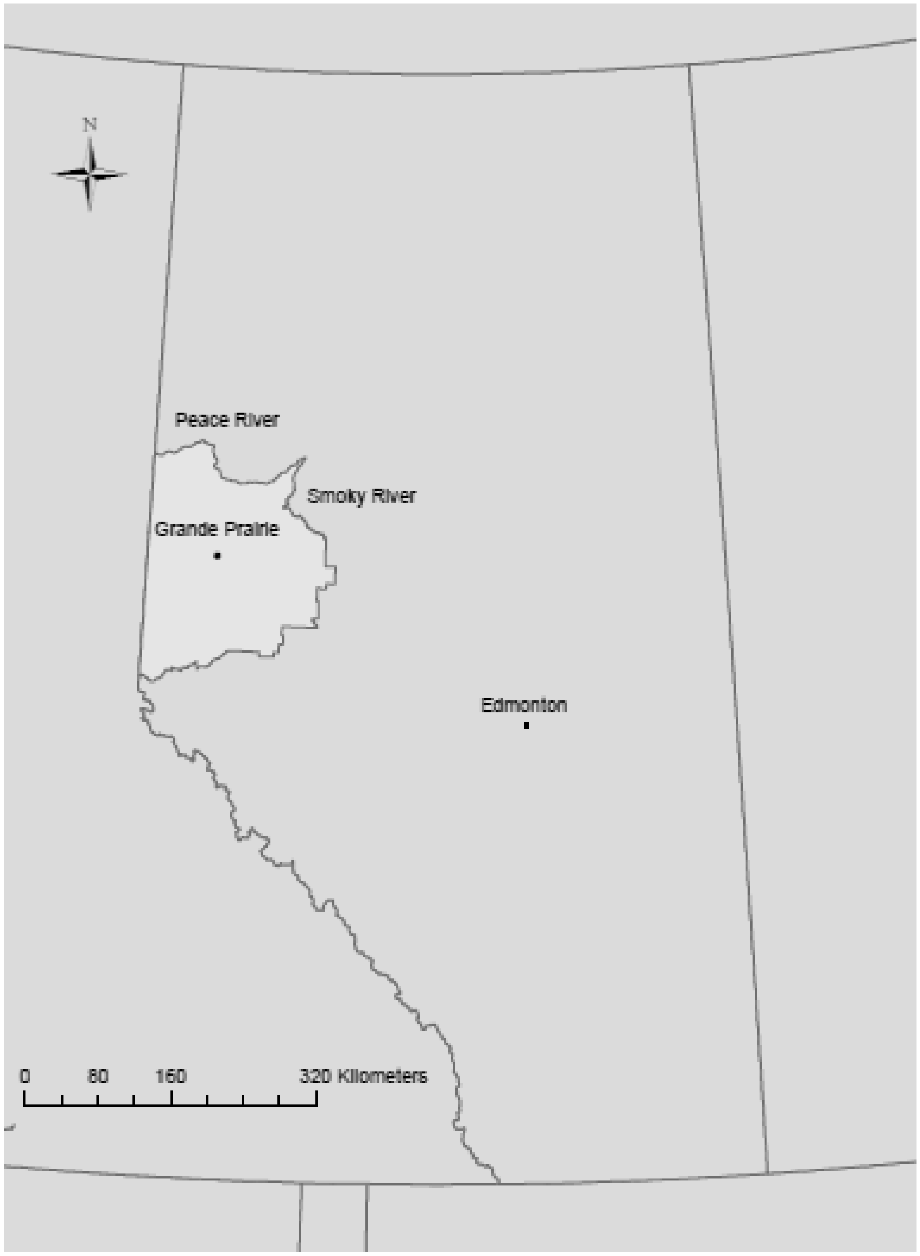

Figure 2.1 – Outlined area around Grande Prairie is the Smoky Management Area. The latitude of Grande Prairie is 55.167 and the longitude is -118.800.

2.2.2 Disturbance Experiment

The range of human detection by Trumpeter Swans was tested on a randomly chosen subsample of lakes. A "disturber" was dressed in blue coveralls and a reflective orange vest, as is typical of industrial worker attire in the region. The disturber then walked along the lakeshore of known nesting lakes until they elicited a recognizable disturbance response from one or both of a nesting pair of swans. In most cases workers were required to approach at the water's margin because expansive rings of emergent vegetation would block the view from shore. Key disturbance responses included head-up alert posture of swans and active movement away from the stimulus. A pedestrian disturbance was chosen because Henson and Grant (1991), Monda *et al*. (1994), and Pease *et al*. (2005) showed this to be the stimulus that caused the strongest reaction in waterfowl, it is an easily administered stimulus and it is a disturbance that may be expected to occur with greater frequency as development increases. The disturber would not step into visual range of swans if they were not greater than 800 m from the swans. This minimum distance was chosen because that is the current suggested no-activity zone by the Alberta Trumpeter Swan Recovery Plan (Alberta Trumpeter Swan Recovery Team 2006). Also preliminary tests during the 2010 field season suggested that swans' threshold of disturbance was this far or further. The ability to accommodate this minimum distance for a > 800 m approach was the only criteria for experimental lake selection. While the disturber approached the swans, a second observer recorded data from a camouflaged blind by constantly observing the swans while maintaining 2-way radio contact with the disturber.

Key swan behavioral responses were noted and when instructed, the disturber took a measurement of the distance to swans with a Bushnell Yardage Pro 1500 range finder to determine disturbance or flight distances. All swan approaches in the experiment were conducted under sunny or mostly sunny conditions with low wind to keep detection levels by swans comparable.

2.2.3 Measuring Human Disturbance

The second portion of this project involved using a GIS (Geographic Information System) to measure distances between anthropogenic developments on the landscape from swan nesting lakes. I measured the distance to the nearest disturbance in this buffer zone including the distance of the nearest well site, oil and gas infrastructure, road, railway, pipeline, power line, and cutline to the nesting lake. I used ArcGIS to create a polygon layer for the nesting lakes in 2000, 2005, and 2010. Swan nesting lakes were identified from GPS locations provided by Alberta Sustainable Resource and Development (ASRD) Fish and Wildlife from the continental breeding surveys carried out during 2000, 2005 and 2010. If a GPS location could not be matched with a water body or it was on a river or creek the point was not considered. Then using the Near Proximity Analysis Tool in Arc Toolbox, I measured the minimum distance to a human disturbance. ASRD Fish and Wildlife also provided the GIS layers for each of the different human disturbances.

After these distance measurements were collected they were compared to the productivity of the Trumpeter Swans for each of the three years. Trumpeter Swan breeding productivity was considered to be the number of cygnets surviving on each lake during the given year until the survey was conducted in late August or early September. These counts came from the Trumpeter Swan Continental Breeding Survey which is a multi-department survey to estimate breeding Trumpeter Swan numbers in North America. It occurs every 5 years in late August through early September when cygnets are large enough to be easily visible and have not fledged and left nesting lakes. If multiple adult pairs were found on a breeding lake and more than 6 cygnets were found on that lake, it was assumed that there were multiple breeding pairs and the average cygnets per brood was used. Linear regressions were used to compare the nesting swan's productivity and distance to each of the human disturbances. A Green/White zone interaction term was added where Green zone was coded as 1 and White zone was coded as 0. Lake size was added as well into the regression as an additional variable. This was done in the statistical program R using lm() and summary(lm()) to return the significance value. Homogeneity of variances and normality in Y for a given X value were tested for each model prior to analysis. This was also done in R using the command Shapiro.test ().

2.2.4 Green vs. White Zones

Land in Alberta is divided into two general categories: either as Green Zone or White Zone. Green areas are publically owned and predominately forested land not available for agriculture, except grazing, and may be permitted for natural resource extraction. These areas are normally found in Alberta's northern foothills and mountainous regions. White areas contain land suitable for cultivation. Most white areas are under private ownership and support a wide range of land uses. Due to the regularity of human disturbance and the different habitat conditions created by human alterations in the white zone, swans may be affected differently by human disturbance than those breeding in the green zone. However, differences in lake conditions and foraging opportunities in agricultural areas between white and green zone lakes may also affect swan productivity and mask the effects of human disturbance. For this reason, swan productivity on each lake for each of the three years was compared between the white and green zones. Lake size of all the nesting lakes were also compared between white and green zones for the three years. This was done using t-tests in R.

2.3 RESULTS

Flight distance tests were conducted on a total of 19 swan pairs nesting on 18 different lakes. The mean distance at which at least one of the swans showed signs of being disturbed was 736±46 m (Figure 2.2). The distance at which the swans were disturbed ranged from 416-1179 m. Of the 19 pairs, 17 of them swam away making alert calls when their disturbance threshold was met. In two instances, one member of the pair, presumably the pen, swam away with the cygnets, and the cob took flight and approached the disturber. The adult that flew at the disturber would circle several times before landing between the disturber and its brood while making repeated alert calls.

Using the information provided from ASRD Fish and Wildlife in 2000, there were 60 lakes with swan nests in the study area, 94 in 2005, and 157 in 2010. These are the same lakes and areas used in the analysis of human disturbance on the landscape. The 2000 and 2005 regressions between cygnet counts per pair and distance to disturbances did not come back with significant results (Table 2.1, Table 2.2, and Table 2.3). In 2010 road, railroad, pipeline, and oil/gas infrastructure came back not significant and well (p=0.03266), power line (p=0.004079), and cutline (p=0.03222) regressions came back significant (Table 2.1 and Table 2.4).

There were several significant differences found between the swans nesting in the white zone and green zones (Table 2.3). For all three years examined, the mean lake size used by swans in the white zone was significantly larger than those in the green zone. In 2010 the average lake size used by swans in the white zone was 105.45 ha (n=62) and 51.47 ha (n=74) in the green zone (Figure 2.3). In 2005 the average lake size used by swans in the white zone was 92.84 ha (n=41) and 68.96 ha (n=46) in the green zone (Figure 2.4). In 2000 the average lake size used by swans in the white zone was 103.96 ha (n=27) and 71.85 ha (n=28) in the green zone (Figure 2.5).

Cygnet count was also found to be significantly different every year between green and white zones. In 2010 the average brood size was 4.07(n=69) cygnets on lakes in the white zone and 3.63(n=88) cygnets in the green zone (p=< 0.001) (Figure 2.6). In 2005 the green zone mean brood count was higher at 3.42(n=53) than the white zone mean brood count of 3.07(n=41) (p=< 0.001) (Figure 2.7). In 2000 the mean brood size was again higher in the white zone with 3.45(n=29) cygnets per breeding lake than the green zone at 3.35(n=31) cygnets (p=< 0.001) (Figure 2.8). Swan counts for each lake were total counts of adults and cygnets per lake in the survey data, so if multiple broods were present on a lake they were treated as one brood.

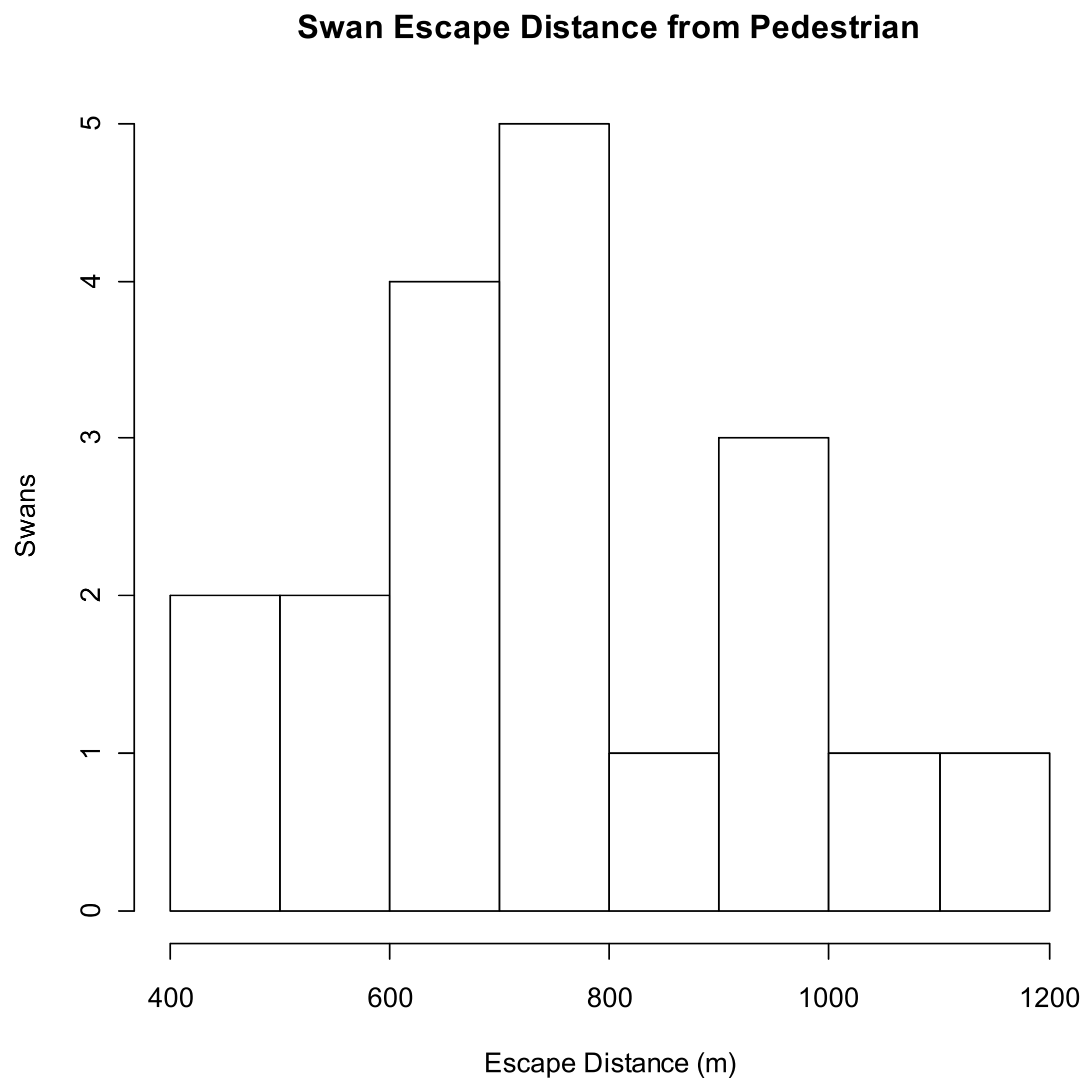

Figure 2.2– The flight distances on 19 pairs of swans exposed to the disturbance experiment, with an average escape distance of 736 m.

Table 2.1 - *P* values from linear regressions between cygnet counts and distance to the different human disturbances with Green/White Zone as an interaction term and including lake area as a variable.

Disturbance	2000	2005	2010
Well sites	0.3893	0.607	0.03266
Road	0.2399	0.1761	0.07092
Railroad	0.2044	0.5307	0.06428
Power line	0.2277	0.8237	0.004079
Pipeline	0.3952	0.8536	0.06687
Oil/Gas Infrastructure	0.2937	0.799	0.07983
Cutline	0.5712	0.839	0.03222

Table 2.2 – Results for the year 2000 disturbance models of linear regressions between cygnet counts and distance to the different human disturbances with Green/White Zone as an interaction term and including lake area as a variable.

Variables	Coefficient	SE	*P*-Values
Well site Model			
Intercept	1.68258	0.98819	0.0945
Well site	0.05524	0.03772	0.149
Green	0.78668	1.15622	0.4992
Lake Area	0.07732	0.04507	0.0921
Well site:Green	-0.04102	0.04478	0.3638
Road Model			
Intercept	2.61635	0.68095	0.000328
Road	0.01531	0.02721	0.5759
Green	-0.61618	0.75818	0.4200016
Lake area	0.0757	0.04449	0.094719
Road:Green	0.01136	0.0302	0.708299
Railroad Model			
Intercept	2.577705	0.797974	0.00213
Railroad	0.003321	0.004789	0.49107
Green	2.145368	1.128088	0.06264
Lake Area	0.061718	0.044566	0.1718
Railroad:Green	-0.01364	0.007097	0.06001
Power line Model			
Intercept	4.384887	0.857127	<0.0001
Power line	-0.014248	0.007628	0.0673
Green	-0.551943	1.10423	0.6193
Lake Area	0.033527	0.04455	0.455
Power line:Green	0.008854	0.010126	0.3859
Pipeline Model			
Intercept	2.00049	0.79757	0.0152
Pipeline	0.04901	0.03208	0.1325
Green	0.98396	0.91264	0.2859
Lake Area	0.06849	0.04421	0.1273
Pipeline:Green	-0.0501	0.03612	0.1712
Oil Infrastructure Model			
Intercept	1.68999	0.85696	0.0538
Oil Infrastructure	0.03633	0.02021	0.078
Green	1.11093	0.95791	0.2514
Lake Area	0.08144	0.04544	0.0788

Variables	Coefficient	SE	*P*-Values
Oil:Green	-0.03521	0.02325	0.1359
Cutline Model			
Intercept	2.999564	0.536514	<0.0001
Cutline	0.007055	0.048816	0.886
Green	0.530399	0.650707	0.419
Lake Area	0.053292	0.044859	0.24
Cutline:Green	-0.103739	0.101866	0.313

Table 2.3 – Results for the year 2005 disturbance models of linear regressions between cygnet counts and distance to the different human disturbances with Green/White Zone as an interaction term and including lake area as a variable.

Variables	Coefficient	SE	*P*-Values
Well site Model			
Intercept	3.65332	0.69653	<0.0001
Well site	-0.03254	0.02719	0.235
Green	-0.33784	0.77212	0.663
Lake Area	0.01061	0.0321	0.742
Well site:Green	0.03298	0.03013	0.277
Road Model			
Intercept	3.656204	0.494888	<0.0001
Road	-0.041283	0.019711	0.0391
Green	-0.595392	0.577912	0.3058
Lake area	0.001647	0.032038	0.9591
Road:Green	0.048828	0.021552	0.026
Railroad Model			
Intercept	3.430439	0.623357	<0.0001
Railroad	-0.003696	0.003953	0.352
Green	-0.62473	0.785998	0.429
Lake Area	0.006347	0.032747	0.847
Railroad:Green	0.007091	0.005201	0.176
Power line Model			
Intercept	3.1124844	0.5376966	<0.0001
Power line	-0.0021761	0.0052515	0.68
Green	0.335714	0.7563574	0.658
Lake Area	0.0151629	0.0321367	0.638
Power line:Green	0.0008045	0.0074404	0.914
Pipeline Model			
Intercept	2.9391844	0.5745512	<0.0001
Pipeline	-0.0005172	0.0224889	0.981
Green	0.2433865	0.666585	0.716
Lake Area	0.016916	0.0324229	0.603
Pipeline:Green	0.003705	0.0252963	0.884
Oil Infrastructure Model			
Intercept	3.193245	0.65078	<0.0001
Oil Infrastructure	-0.006421	0.015238	0.675

Variables	Coefficient	SE	*P*-Values
Green	0.336229	0.721047	0.642
Lake Area	0.010394	0.03307	0.754
Oil:Green	0.002559	0.017121	0.882
Cutline Model			
Intercept	2.872459	0.39985	<0.0001
Cutline	0.009005	0.023175	0.699
Green	0.440025	0.461533	0.343
Lake Area	0.01136	0.032079	0.616
Cutline:Green	-0.011725	0.054747	0.831

Table 2.4 – Results for the year 2010 disturbance models of linear regressions between cygnet counts and distance to the different human disturbances with Green/White Zone as an interaction term and including lake area as a variable.

Variables	Coefficient	SE	*P*-Values
Well site Model			
Intercept	4.80882	0.62503	<0.0001
Well site	-0.03634	0.02363	0.1261
Green	-1.60576	0.67068	0.0179
Lake Area	0.01314	0.02501	0.6
Well site:Green	0.04136	0.02552	0.1071
Road Model			
Intercept	4.24182	0.44471	<0.0001
Road	-0.01644	0.02005	0.4137
Green	-0.97941	0.4971	0.0507
Lake area	0.01693	0.0248	0.4972
Road:Green	0.01862	0.02114	0.3798
Railroad Model			
Intercept	4.3256	0.0465859	<0.0001
Railroad	-0.002829	0.002953	0.3397
Green	-1.144642	0.380206	0.0945
Lake Area	0.017799	0.023951	0.4586
Railroad:Green	0.003833	0.004321	0.3766
Power line Model			
Intercept	4.899499	0.428231	<0.0001
Power line	0.012088	0.004387	0.0066
Green	-1.476569	0.593627	0.014
Lake Area	0.013089	0.023349	0.05759
Power line:Green	0.011581	0.005812	0.0482
Pipeline Model			
Intercept	4.30172	0.49846	0.0001
Pipeline	-0.01571	0.01857	0.3989
Green	-1.07843	0.53723	0.0465
Lake Area	0.01824	0.02464	0.4602
Pipeline:Green	0.01901	0.01988	0.3407
Oil Infrastructure Model			
Intercept	3.992438	0.535271	0.0001
Oil Infrastructure	-0.001606	0.01244	0.897
Green	-0.904373	0.599001	0.133
Lake Area	0.024458	0.024405	0.318

Variables	Coefficient	SE	*P*-Values
Oil:Green	0.005841	0.013744	0.671
Cutline Model			
Intercept	4.094	0.30642	0.0001
Cutline	-0.03189	0.02773	0.2521
Green	-1.02292	0.3564	0.0047
Lake Area	0.02417	0.02407	0.3168
Cutline:Green	0.06852	0.04186	0.1038

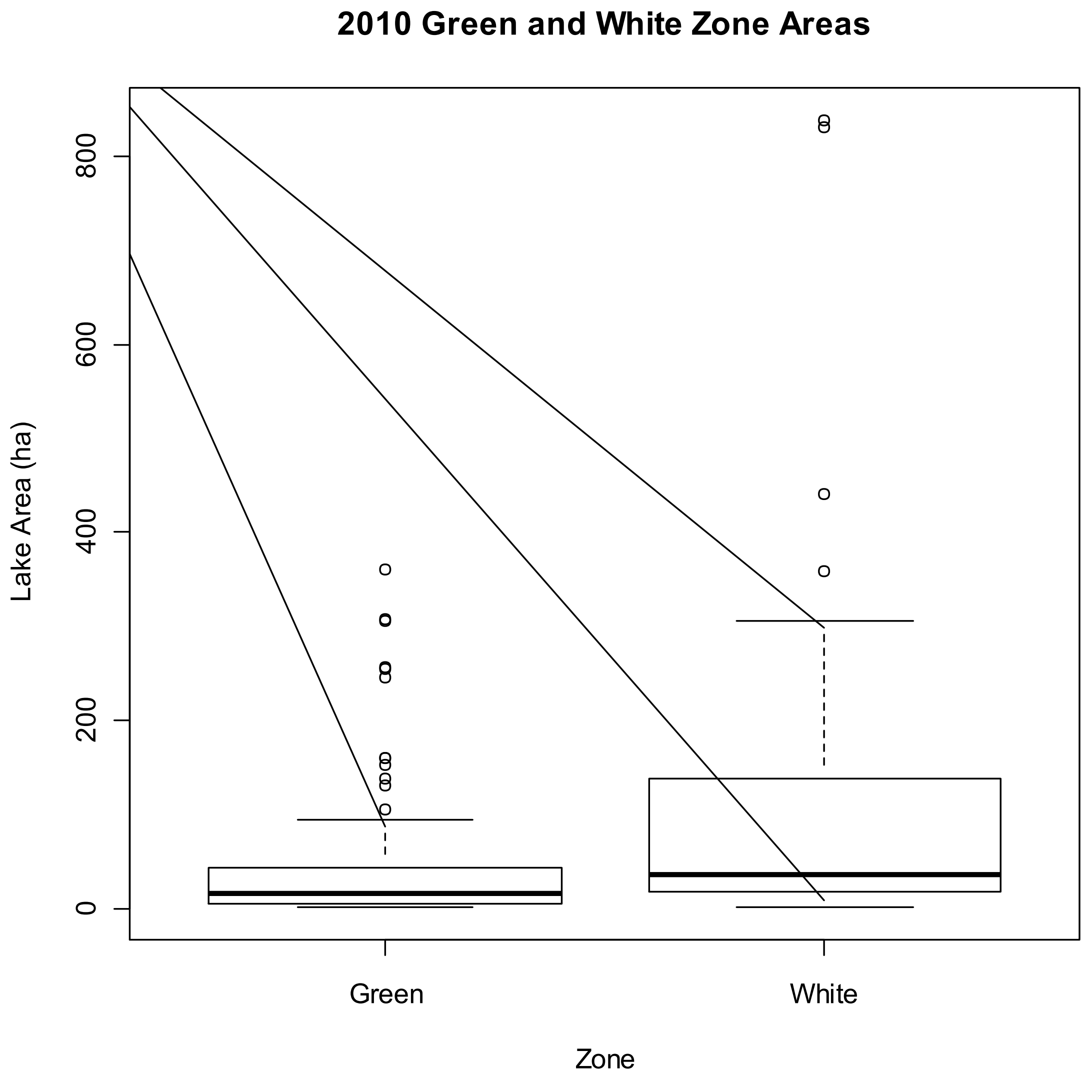

Figure 2.3 – The distribution of swan nesting lake areas in the green (n=74) and white (n=62) zones in 2010. The upper and lower whiskers in this graph represent the 100th and 0 percentile respectively. The upper and lower bars of the interquartile range are the 75th and 25th percentile respectively. The darker inner line indicates the median. Any outliers are represented as circles.

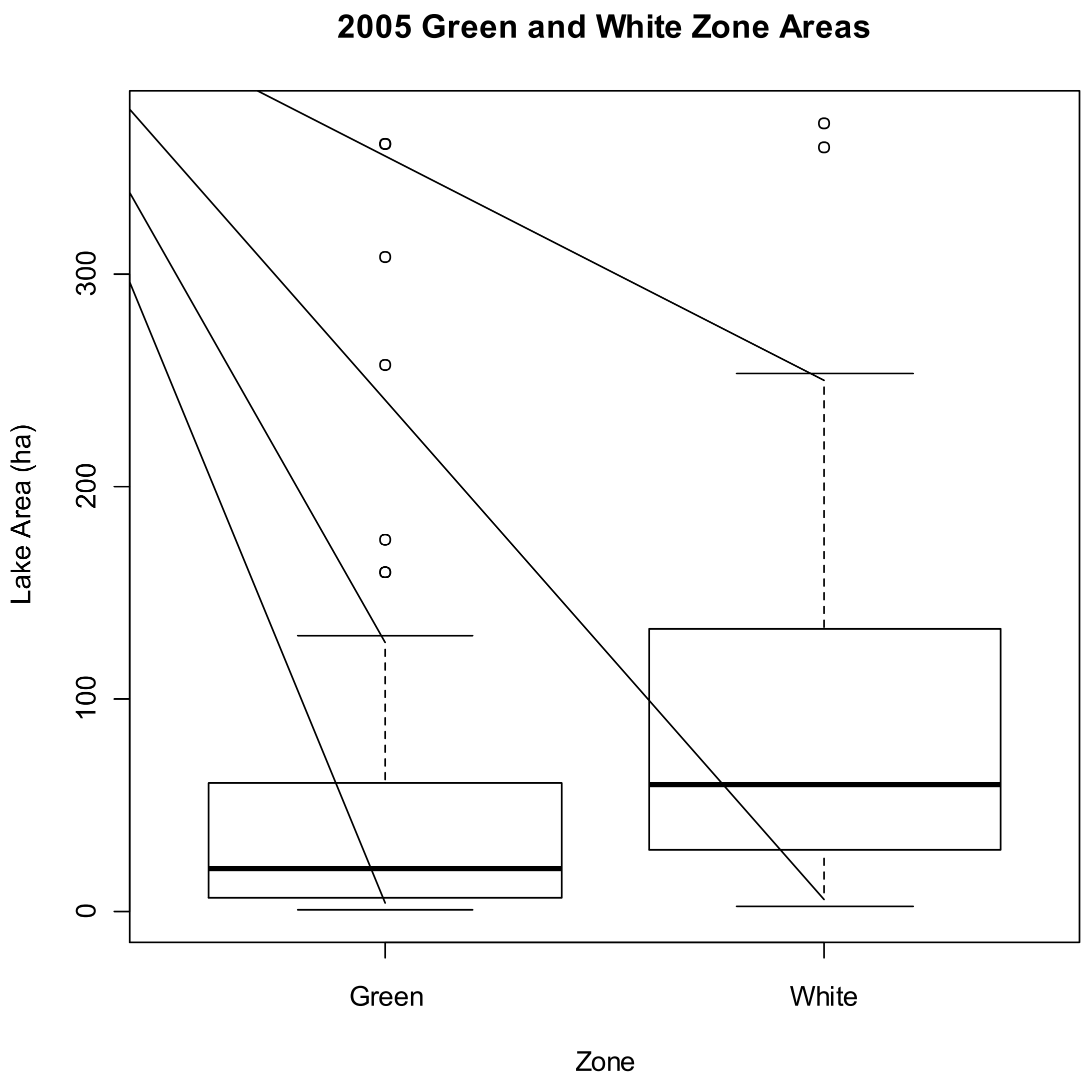

Figure 2.4 – The distribution of swan nesting lake areas in the green (n=46) and white (n=41) zones in 2005.

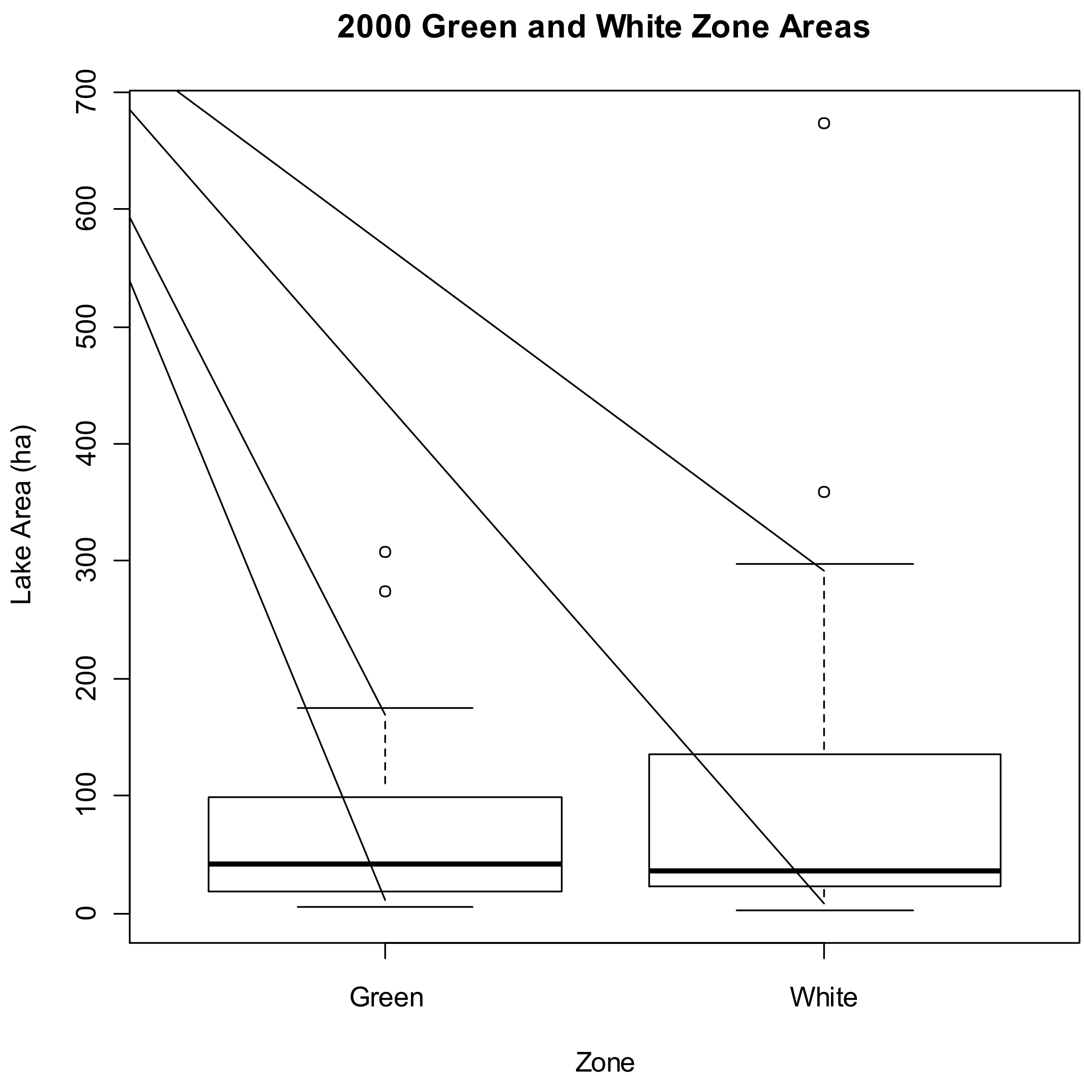

Figure 2.5 – The distribution of swan nesting lake areas in the green (n=28) and white (n=27) zones in 2000.

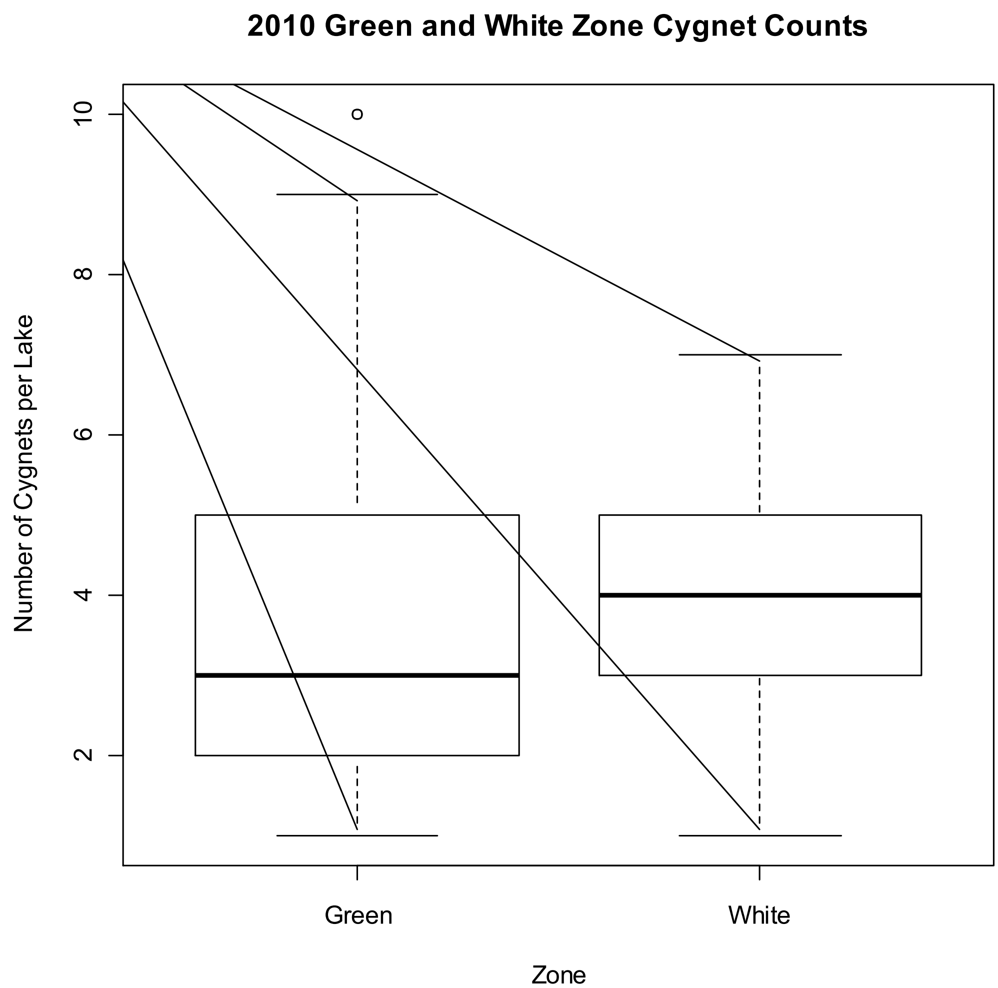

Figure 2.6 – The distribution of cygnets per breeding lake in 2010 with an average of 3.63 cygnets per lake in the green zone and 4.07 in the white zone.

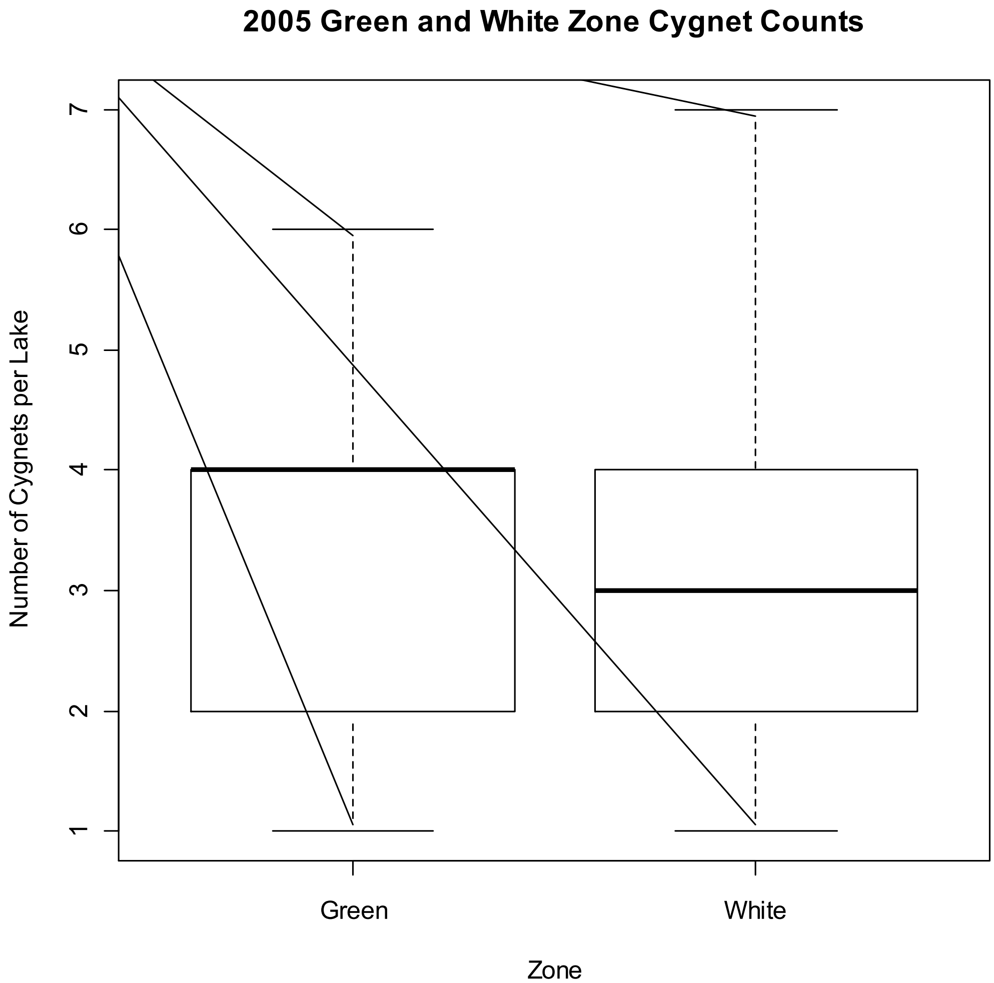

Figure 2.7 – The distribution of cygnets per breeding lake in 2005 with an average of 3.42 cygnets per lake in the green zone and 3.07 in the white zone.

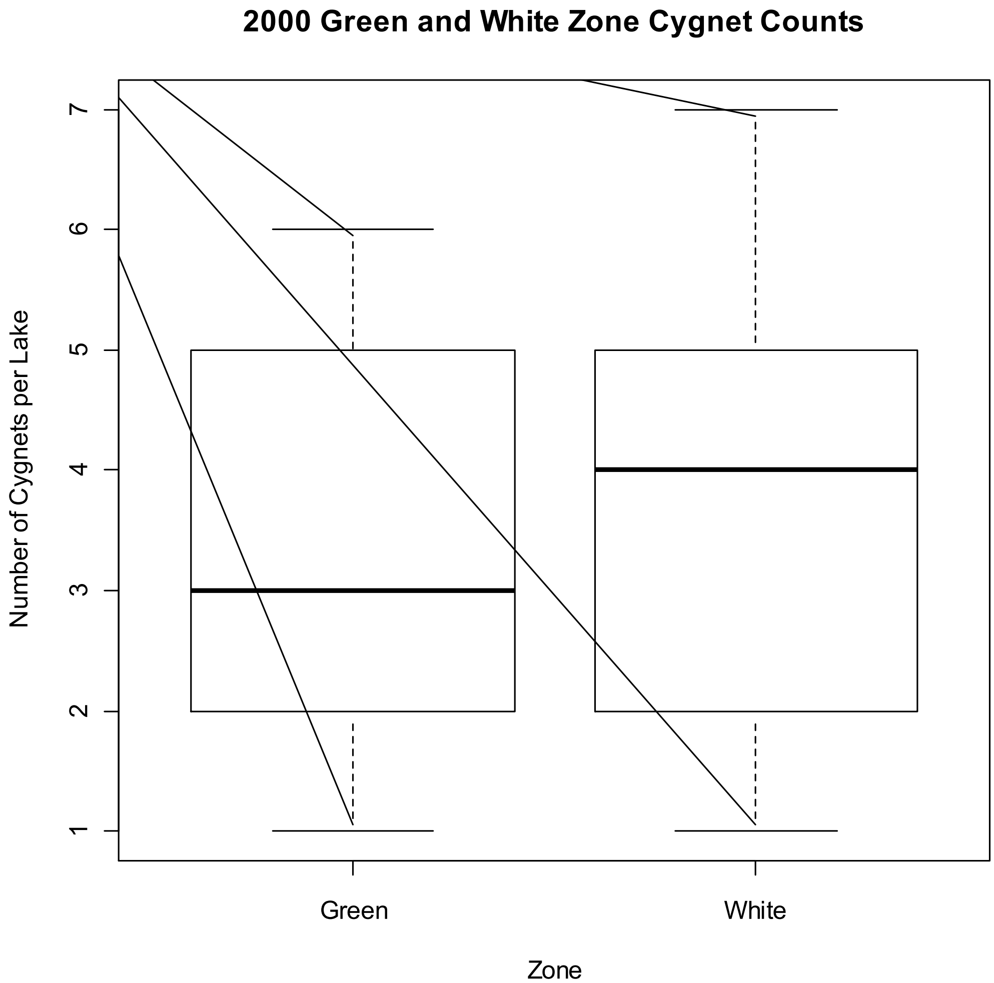

Figure 2.8 – The distribution of cygnets per breeding lake in 2000 with an average of 3.35 cygnets per lake in the green zone and 3.45 in the white zone.

2.4 DISCUSSION

2.4.1 Disturbance and Swans

I found only three significant results using linear regressions of cygnet counts per brood and distance to human disturbance with green/white zone as an interaction variable and lake size. The three human disturbances whose models were significant were well sites, power lines, and cut lines. In the well site model the only variable that was significant was the Green/White zone variable. It had a negative relationship with cygnet count meaning White zones had higher cygnet counts. This was to be expected from the t-tests done between green and white zones. In the power line model both power line and Green/White zone variables were significant. Distance from power lines had a positive relationship to cygnet counts per brood. During the field experiments it was common that power lines were often kept clear. Cutting vegetation underneath them may have well been a yearly event which would have been a large source of disturbance. These large clear paths would also make it easier for humans and predators to travel which may also increase disturbance to swans nesting near them. The Green/White zone variable again had a negative relationship with cygnet counts suggesting cygnet counts were again higher in white zones. The only significant variable in the cutline model was the Green/White Zone variable with a negative relationship. The cutline variable included all sizes of cutlines from small exploratory lines to large access lanes for equipment which meant there was a wide range of disturbance that these could open up the lakes too.

These few significant results were unexpected with trumpeter swans thought to be sensitive to human disturbance (Banko 1960, Henson and Grant 1991). However this may be because of confounding factors such as lake size and breeding habitat quality. The small sample size of breeding lakes also makes it harder to find relationships by statistical means. Lakes in the white zones tended to have well sites closer to them than lakes in the green zone, which had lower cygnet counts. Habituation of swans in the white zone would also influence how the swans react to human activity at well sites. Also human disturbance is measured here by distance to well heads which gives no indication of extent and frequency of use. Static well heads, especially if inactive, shut in and rarely visited would not be expected to be a noticeable or threatening feature in the landscape. The Alberta Trumpeter Swan Recovery Team (2006) has recommended restricted land use activity within 800 m of nesting lakes' high water marks. This land use guideline limits the amount of human activity on such landscape features such as well sites, oil and gas infrastructures, power lines, pipelines, and cut lines near swan nesting lakes during the breeding season. During the course of the field work, ongoing recreational activities were observed inside the buffer zone including camping, boating, and use of all-terrain vehicles (ATVs). Features such as roads are general access features and do not see a decrease in use because of the land use guidelines as currently enforced. As long as these roads are used by vehicles and not pedestrians they may not be a significant source of disturbance to the swans as well (Henson and Grant 1991, Pease *et al*. 2005). Nesting success may not be correctly represented by the data set from the 5-year breeding surveys. Surveys were generally conducted in late August or early September when cygnets were large enough to be easily counted. Entire nest and brood loss that occurs before the surveys due to either human disturbance or natural causes are not represented in the surveys. Survival of cygnets can be highly variable with reports ranging from 24-84%. Survival may be influenced by human disturbance (Corace III *et al.* 2006).

The analyses took into account the distance to each of the nearest human disturbances, but did not take into account the amount of the disturbances in the buffer zone or the frequency of use from humans of the disturbance features. This meant cumulative swan disturbance was not considered. The analyses also incorporated only a few human disturbances on the landscape, excluding other important features such as houses, parks, and boat launches or single episodes of human activity (e.g. firearms discharge, personal watercraft operation or float plane landings) that may have an effect on swan productivity. Houses and parks may be an important source of disturbance in developed areas because they would be a constant source of pedestrian disturbance to swans. A select few pairs have been able to habituate to such disturbances in the agricultural area near Grande Prairie and at Saskatoon Provincial Park. Boat access may also be a significant source of disturbance to nesting swans from either a behavioral or due to excessive wave action on nests constructed close to the waterline. Saskatoon Lake did not have successful nesting swans in 2000 and 2005, but did in 2010 when lake levels were too low for boat access. It is noteworthy that lakes such as Musreau and Sturgeon in the study area appeared suitable for swans but had high boat traffic; as a likely consequence, they did not support successful swan nests in any of the survey years. The buffer zones used for the analysis were based on visual extent to which swans may be affected by a pedestrian disturbance. Many of the lakes on which swans nested were situated in forested areas, or had a forested boundary around them. Trees may serve to limit auditory and visual cues that could affect which swans are affected by human disturbances.

Human disturbance may be affecting swans but not in the ways hypothesized. Disturbance may be affecting a higher decision point in the settling behavior of swans as they opt to avoid nesting attempts in overly active areas. If they practice avoidance early enough in their selection, it need not influence nesting success very much unless the number of suitable lakes is a limiting factor. Swans are able to assess breeding lakes and chose lakes on which they have an increased chance of successfully fledging young (Proffitt *et al*. 2010). It's been shown that certain human disturbances such as transportation infrastructures have a negative influence on occupancy of swan nesting lakes (Schmidt *et al*. 2009). Human disturbance may not be having a significant influence on productivity because swans are choosing nesting lakes they feel will adequately meet their nesting needs, which includes amount of disturbance.

2.4.2 Swan use of Green versus White Zones

There were differences in white and green zone lake size and breeding productivity for the three years. Sizes of breeding lakes averaged larger for all three years in the white zone while cygnet production was also higher in the white zone in 2010 and 2000 but was higher in the green zone in 2005. Wetland size has been correlated with Trumpeter Swan clutch size which may explain the higher productivity in the white zone (Proffitt *et al*. 2010) although land use and soil fertility differ between the green and white zones as well. During the same time of this study, observations for cygnet survival were being taken and the start of hatching in green zones was almost two weeks later than the initial hatching in white zones (unpublished data). Artic nesting geese that initiate nesting later tend to have smaller clutch sizes and poorer hatching success which may explain the lower productivity in the late hatching green zone swans (Newton 1977). Trumpeter swans are selective of breeding habitat and choose nesting lakes to maximize probabilities of successful reproduction (Proffitt 2010). Trumpeter swans occupy larger wetlands such as lakes and ponds more frequently than shrubby or forested wetlands (Schmidt 2009). These larger lakes and ponds with less shrub and forest cover are the more common lake configuration in the white zone and might be chosen because they present a greater chance of successful reproduction. Habituation may also be aiding the swans in nesting on these higher disturbance white zone lakes, but at their more favorable sizes, configuration and seasonality could represent mitigating factors in nesting and brood survival opportunities that outweigh disturbance. Waterfowl have been shown to habituate to human disturbances which may allow Trumpeters to adapt to the disturbed nesting lakes in the white zone (Conomy *et al*. 1998).

With Trumpeter Swan populations rebounding in Alberta, the extent of human disturbance on their recovery may come into question. Even though the results did not show statistical significance between breeding productivity and multiple forms of human disturbance on the landscape, I believe it is prudent to maintain at least some levels of restriction to help ensure recovery of populations to historic levels. With Trumpeter Swans nesting in the sometimes highly agricultural white zones, there is evidence and precedent that habituation to human presence is a possibility. However most of the lakes on which they are successful in white zones are much larger than the lakes used in remote green zones and have visual barriers on the shoreline, giving the swans opportunities to avoid human disturbances or at least the options of distancing themselves or escaping distressing stimuli. Through the disturbance experiments it was found that even these swans are easily disturbed by the presence of humans and if this were to occur during the sensitive time of egg incubation. Because incubation is a process that does not allow breaks in its continuity, especially during cold or wet weather, such disturbance could negatively impact nesting success.

2.5 REFERENCES

Alberta Trumpeter Swan Recovery Team. 2006. Alberta Trumpeter Swan Recovery Plan, 2005-2010. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Recovery Plan No. 12. Edmonton, AB.

Banko, W.E. 1960. The Trumpeter Swan. North American Fauna No. 63, U.S. Fish and Wildlife Service, Washington, DC.

Bellrose, F.C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

Boudreau, G.W. 1968. Alarm sounds and responses of birds and their application in controlling problem species. *Living Birds* 7: 27-46.

Burton, N.H.K., M.J.S. Armitage, A.J. Musgrove, and M.M. Rehfisch. 2002a. Impacts of man-made landscape features on numbers of estuarine waterbirds at low tide. Environmental Management 30: 857-864.

Burton, N.H.K., M.M. Rehfisch, and N.A. Clark. 2002b. Impacts of disturbance from construction work on the densities and feeding behavior of waterbirds using the intertidal mudflats of Cardiff Bay, UK. Environmental Management 30: 865-871.

Conomy, J.T., J.A. Dubovsky, J.A. Collazo, and W.J. Fleming. 1998. Do Black Ducks and Wood Ducks habituate to aircraft disturbance? *Journal of Wildlife Management* 62: 1135-1142.

Corace III, R.G., D.L. McCormick, and V. Cavalieri. 2006. Population growth parameters of a reintroduced trumpeter swan flock, Seney National Wildlife Refuge, Michigan, USA (1991-2004). *Waterbirds* 29: 38-42.

Dingemanse, N.J., C. Both, P.J. Drent, and J.M. Tinbergen. 2004. Fitness consequences of avian personalities in a fluctuating environment. *Proceedings of the Royal Society of London Series B-Biological Sciences* 271: 847-852.

Fish and Wildlife Division. 2004. Report of Alberta's Endangered Species Conservation Committee: June 2002. Alberta Sustainable Resource Development, Fish and Wildlife Division, Edmonton, AB.

Groves, D.J. 2012. The 2010 North American trumpeter swan survey. U.S. Fish and Wildlife Service, Division of Migratory Bird Management, Juneau, Alaska, USA.

Henson P. and J.A. Cooper. 1993. Trumpeter Swan incubation in areas of differing food quality. *Journal of Wildlife Management* 57: 709-716.

Henson, P. and T.A. Grant. 1991. The effects of human disturbance on Trumpeter Swan breeding behavior. *Wildlife Society Bulletin* 19: 248-257.

Holton, G. 1982. Habitat use by trumpeter swans in the Grande Prairie region of Alberta. Thesis, University of Calgary, Calgary, Canada.

James, M.L. 2000. Status of Trumpeter Swan (Cygnus buccinator) in Alberta. Alberta Environment, Fisheries and Wildlife Management Division, and Alberta Conservation Association, Wildlife Status Report No. 26, Edmonton, AB.

Keller, V.E. 1991. The effect of disturbance from roads on the distribution of feeding sites of geese (*Anser brachyrhynchus, A. anser*), wintering in north-east Scotland. *Ardea* 79: 229-232.

Klein, M.L., S.R. Humphrey, and F. Percival. 1995. Effects of ecotourism on distribution of waterbirds in a wildlife refuge. *Conservation Biology* 9: 1454-1465.

LaMontagne, J.M., L.J. Jackson, and R.M.R. Barclay. 2003. Characteristics of ponds used by trumpeter swans in a spring migration stopover area. *Canadian Journal of Zoology* 81: 1791-1798.

Milsom, T.P., D.C. Ennis, D.J. Haskell, S.D. Langton, and H.V. McKay. 1998. Design of grassland feeding areas for waders during winter: the relative importance of sward, landscape factors and human disturbance. *Biological Conservation* 84: 119-129.

Mitchell, C.D. 1994. Trumpeter swan (*Cygnus buccinators*): The birds of North America. The Academy of Natural Sciences, Philadelphia, Pennsylvania, USA and The American Ornithologists' Union Number 105, Washington, D.C., USA.

Monda, M.J., J.T. Ratti, and T.R. McCabe. 1994. Reproductive ecology of Tundra Swans on the Arctic National Wildlife Refuge, Alaska. *Journal of Wildlife Management* 58: 757-773.

Mori, Y., N.S. Sodhi, S. Kawanishi, and S. Yamagishi. 2001. The effect of human disturbance and flock composition on the flight distance of waterfowl species. *Journal of Ethology* 19: 115-119.

Natural Regions Committee 2006. Natural Regions and Subregions of Alberta. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. T/852.

Newton, I. 1977. Timing and success of breeding in tundra nesting geese. Pages 113-126 *in* B. Stonehouse and C.M. Perrins, eds. Evolutionary Ecology. Macmillan Publishing, London, U.K.

Page, R.D. 1974. The ecology of the trumpeter swam on Red Rock Lakes National Wildlife Refuge, Montana. Final Report, U.S. Fish and Wildlife Service, Region 1.

Pease, M.L., R.K. Rose, and M.J. Butler. 2005. Effects of human disturbances on the behavior of wintering ducks. *Wildlife Society Bulletin* 33: 103-112.

Proffitt, K.M., T.P. McEneaney, P.J. White, and R.A. Garrott. 2010. Productivity and fledging success of trumpeter swans in Yellowstone National Park, 1987-2007. *Waterbirds* 33: 341-348.

Schmidt, J.H., M.S. Lindberg, D.S. Johnson, and J.A. Schmutz. 2009. Environmental and human influences on Trumpeter Swan habitat occupancy in Alaska. The Condor 111: 266-275.

3 Modeling Trumpeter Swan Populations

3.1 INTRODUCTION

3.1.1 Trumpeter Swan Aerial Surveys

Starting in the 1950's, aerial surveys became an important assessment tool for wildlife managers to monitor Trumpeter Swan numbers in Alberta. Aerial surveys have been useful and effective for counting Trumpeter Swans because these birds are distributed over large areas of the landscape based on suitable nesting lakes, and they are easily detectable from the air because of large body size and coloration. The first Trumpeter Swan survey (ground level) was conducted in 1944 in the Grande Prairie, Alberta region with 64 adults and 14 cygnets counted. The first aerial survey was conducted in 1954 with a total minimum count of 232 swans (Mackay 1981). Starting in 1957 and continuing on to 1980, the Canadian Wildlife Service (CWS) conducted yearly annual fall surveys to monitor Trumpeter Swan numbers. First in 1968, and later in 1975, extensive aerial surveys were conducted over the entire known breeding range of Trumpeter Swans in North America (Moser 2006). From 1975 until present, this extensive breeding range survey has been conducted every 5 years until present to determine total Trumpeter Swan numbers in North America.

The majority of Trumpeter Swan aerial surveys in Alberta have been conducted from fixed-wing aircraft with a pilot and an observer observing on opposite sides of the plane (Beyersbergen 2007). More recently some wildlife biologists have started using helicopters for surveying small areas and also for surveying high-density swan-nesting areas for safety reasons. Aircraft would normally fly at elevations of 150-300 m above the ground at speeds of approximately 100-150 km/h. The observer seated next to the pilot would navigate as well as keep counts on the swans. The survey areas would include all known lakes swans have occupied during past surveys. Bodies of water where incidental swan sightings had occurred between surveys were checked as well. Surveys were expanded to water bodies near known breeding lakes that appeared suitable for nesting. The results of these surveys were considered a total minimum population count for the region. Current surveys have been increasing in cost because of increases in swan population and area occupied (Figure 3.1, Figure 3.2, and Figure 3.3).

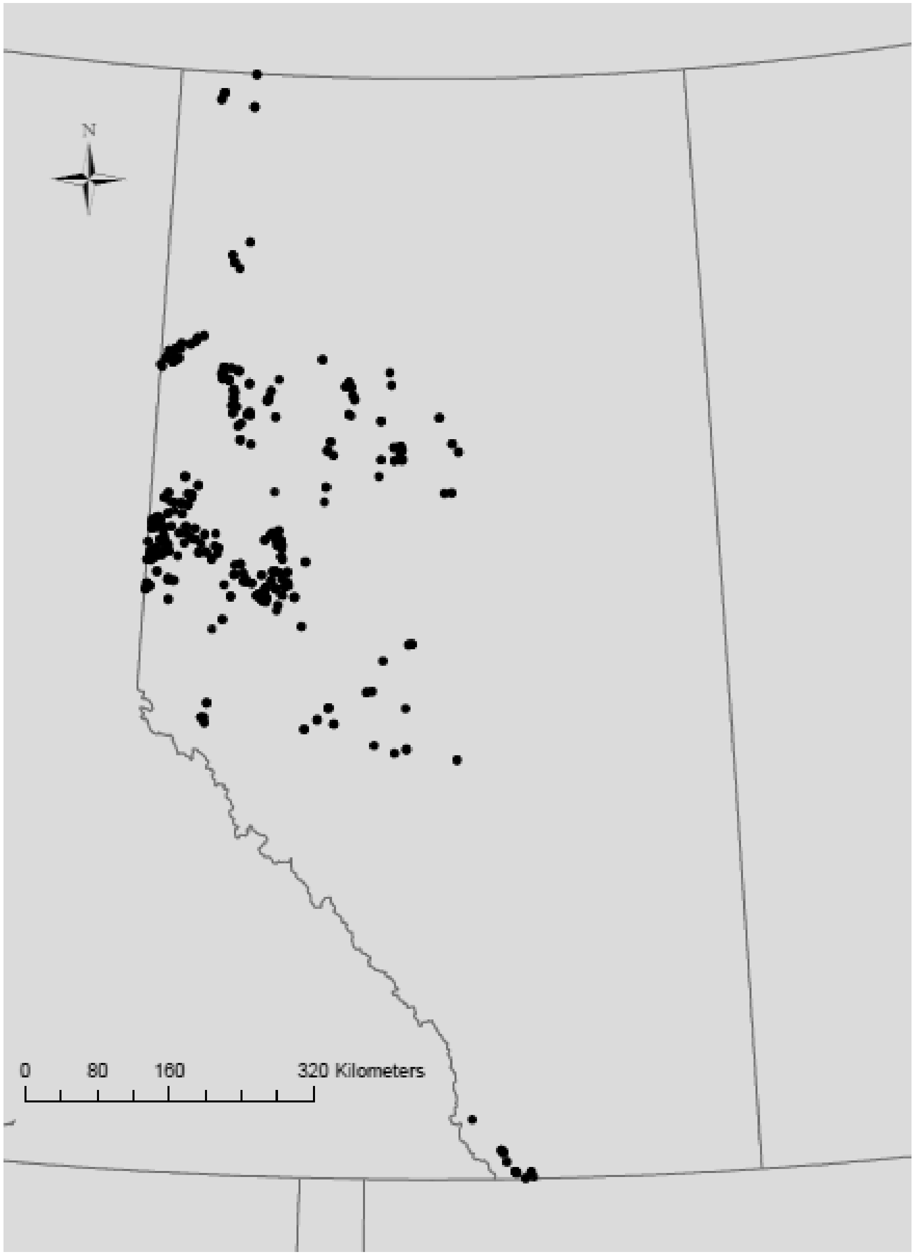

Figure 3.1 – 2000 Trumpeter Swan Survey swan locations, excluding Elk Island National Park flock.

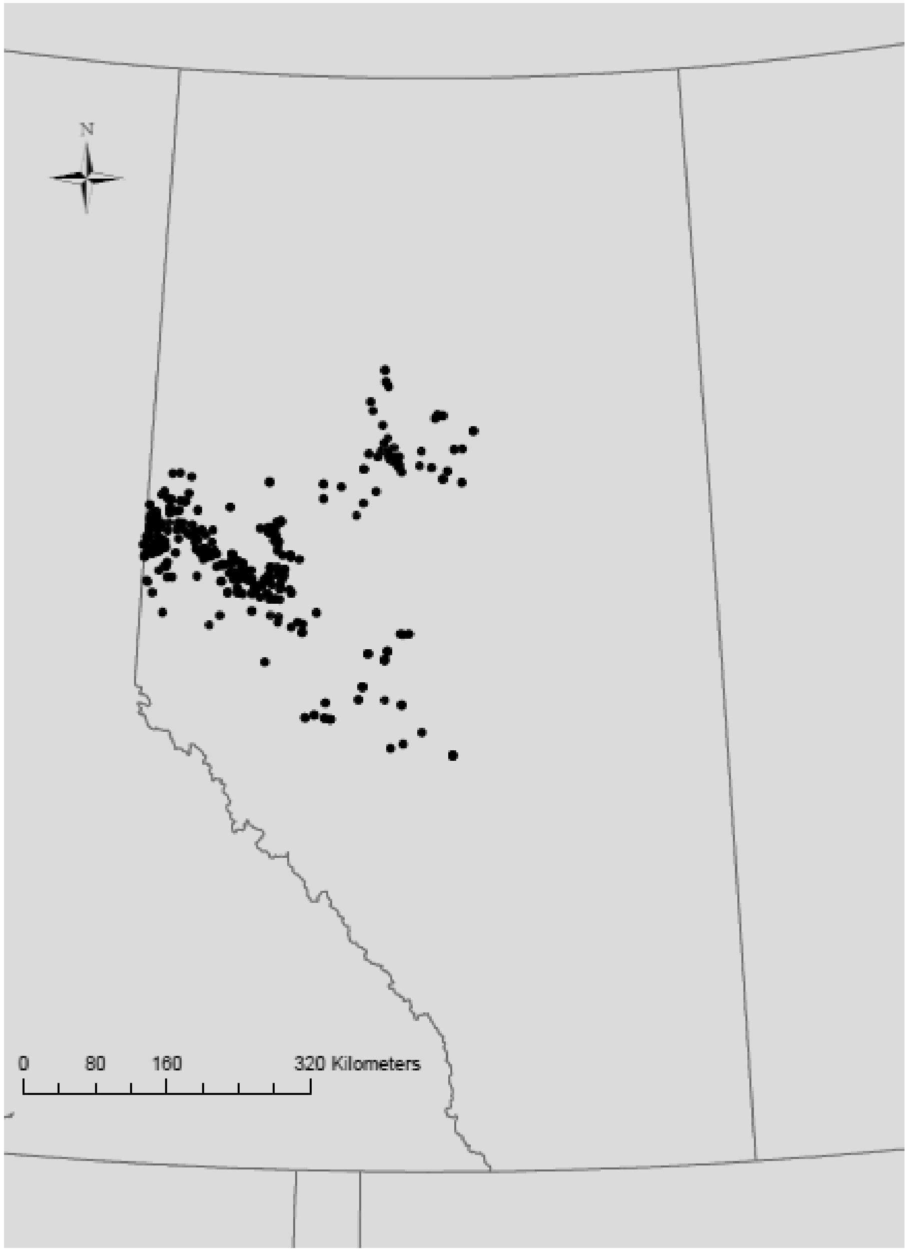

Figure 3.2 – 2005 Trumpeter Swan Survey swan locations, excluding Elk Island National Park, Peace River, High Level and Pincher Creek flocks.

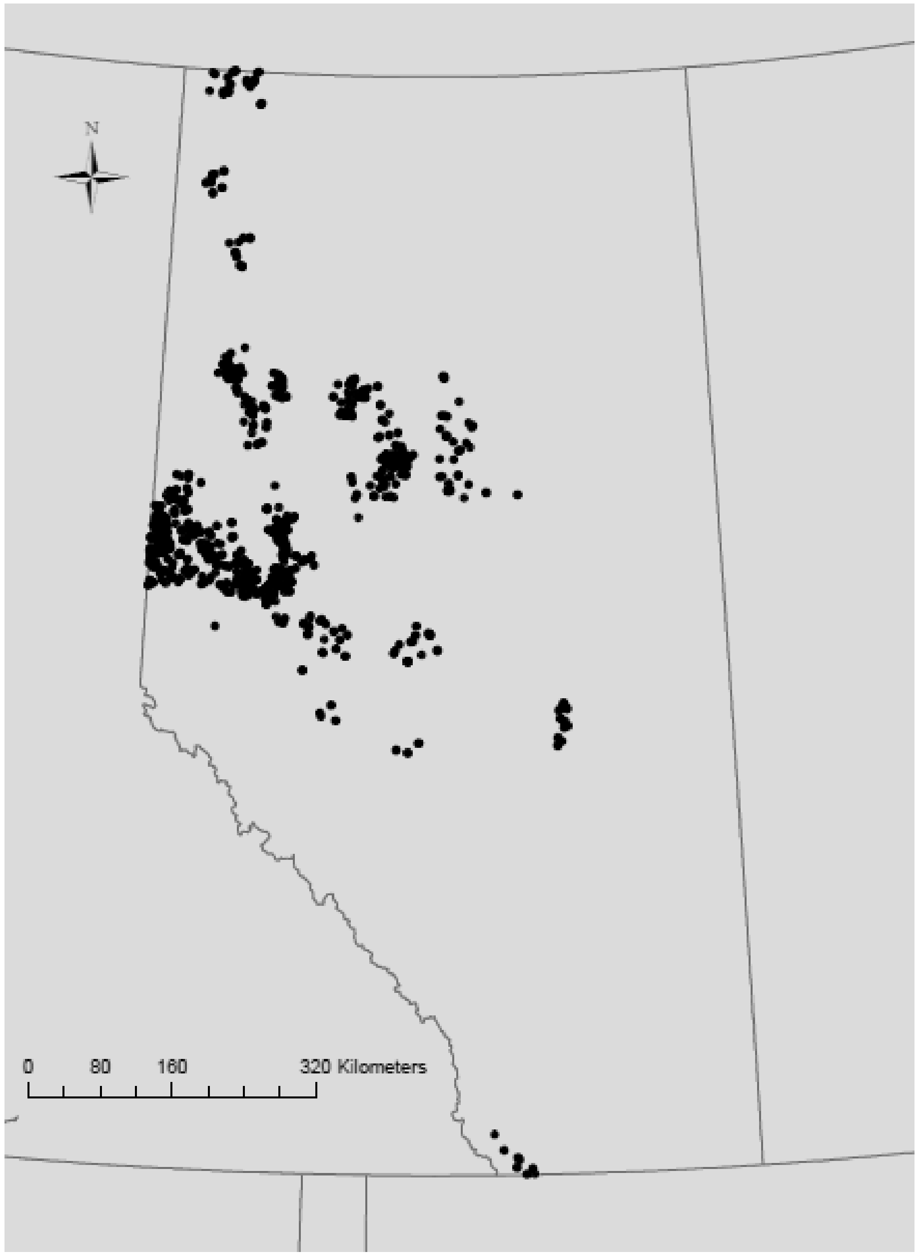

Figure 3.3 – 2010 Trumpeter Swan Survey swan locations. A stratified sampling method was used for this survey and only a portion of the blocks were surveyed.

3.1.2 Stratified Random Sampling

Stratified random sampling is a method of surveying an extrapolatable subset of a population or its habitat without having to cover the entire range. This can be a useful survey method when considering the limited budgets most wildlife managers have at their disposal and the expenses of equipment and humans. The first step of stratified sampling is to divide the population into subpopulations or strata. A random sample is drawn from all possible strata to represent the whole population. In theory this method gives a more accurate population estimate than similar methods, such as simple random sampling, because it acknowledges that the sampled population isn't homogeneous throughout its entire occurrence and represents all levels of strata (Snedecor and Cochran 1989). This survey method has proven effective when sampling Greater Snow Geese (*Anser caerulescens atlanticus)* (Reed *et al.* 1992 and Reed and Chagnon 1987). In these studies the strata of dense, moderate, and sparse goose densities, were based on habitat evaluation that was supported by experimental surveys. They were able to cover only 21% of the survey area and achieve 84% precision in their population estimations.

A stratified random sampling method was first used to estimate Trumpeter Swan population numbers in Alaska in 1986 (Conant *et al.* 1991). In 1995 and then again in 2000 this method was used for estimating swan numbers in parts of the Yukon and British Columbia (Hawkings 2000). This survey method was implemented in these areas because of the large amount of remote area in these regions in which little is known about the swan population. This method was first used in 1995 in Canada with imprecise results because of poor stratification. With increased data on swan distribution, swan stratification accuracy has improved as have the population estimates for 2000. Four density strata were used in 2000: Stratum 0 where swans were thought to not occur, Stratum 1 where swans haven't been documented but where suitable nesting habitat exists, Stratum 2 in which 1-10 swans were predicted to occur, and Stratum 3 where 11+ swans were expected (Hawkings *et al.* 2002). Sampling units were based on 1:50,000 maps. This method is similar to what the Canadian Wildlife Service used in Alberta for the 2010 Trumpeter Swan continental survey (Figure 3.4). Conant *et al.* (2002) suggested that this survey method be extended and used in the continental breeding survey based on the increase in Trumpeter Swan numbers and range.

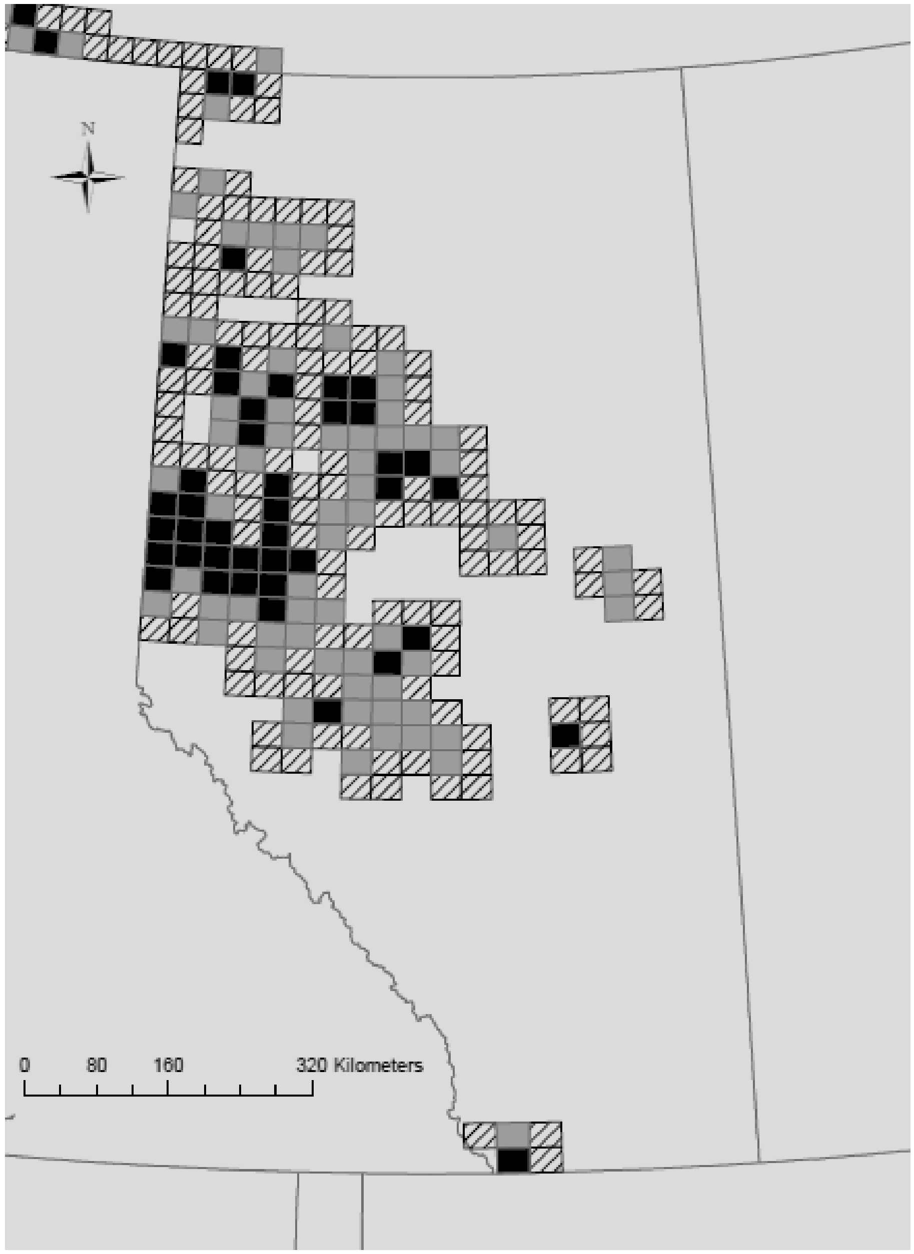

Figure 3.4 – 2010 Trumpeter Swan Survey blocks. Black colored blocks are expected to have 11+ swans, grey blocks are expected to have 1-10 swans, and hatched blocks are expected to have 0 swans.

3.1.3 Objectives

My objective was to assess the effectiveness of population estimation of Trumpeter Swans in Alberta through the use of stratified random sampling and explore possible modifications to increase its effectiveness.

3.2 METHODS

A stratified random sampling method for Trumpeter Swans in Alberta was developed using historical records of surveys to parameterize strata and to test the survey's design accuracy. According to Snedecor and Cochran (1989) there are three steps in random stratified sampling. The steps for this sampling method are to first divide the population into strata, draw a random sample from the strata, and finally to estimate the population size. To define the strata, a sample unit size must first be determined. The same survey blocks used in the 2010 Trumpeter Swan survey of size 30 minutes latitude by 15 minutes longitude were used. A select survey area was also chosen instead of Alberta's entire population because survey data were not available for all areas for every year (Figure 3.5). Also the Elk Island National Park flock and Pincher Creek flock are both small and isolated from the rest of the Alberta population and have been surveyed separately by local biologists. The 2000 Trumpeter Swan survey data were used to determine the number of swans in each block. Using a histogram to observe the frequency of adult swan numbers per block, strata were created by locating natural breaks to determine cut offs for stratum size and to improve homogeneity in each stratum. Four strata were used including 0, low, medium, and high swan numbers. Fifty percent of the total survey area was surveyed, and the blocks surveyed in each stratum were divided up evenly.

After calculating the number of blocks needed to be surveyed in each stratum, the blocks were randomly selected from each stratum. The total population size of swans in the survey area was first estimated for the year 2000 to test if this method could accurately predict the total population. To calculate total population estimates the following equations were used (Cochran 1977):

$$\bar{y}_h = \frac{\sum_{i=1}^{n_h} y_{hi}}{n_h}$$

$$\bar{y}_{st} = \frac{\sum_{h=1}^{L} N_h \bar{y}_h}{N}$$

$$\hat{Y}_{st} = N\bar{y}_{st}$$

In these equations $\bar{y}_{h,}$ is the sample mean for the h^{th} stratum, $\bar{y}_{st}$ is the estimation of the population mean, and $\hat{Y}_{st}$ is the total population estimate. The variables N_h is the total number of sampling units in the h^{th} stratum, N is the total number of sampling units, n_h is the number of units sampled in the h^{th} stratum, and y_{hi} is the swan count of the i^{th} block in the h^{th} stratum. The process of block selection and population estimation was repeated 100 randomly computer generated times for the year 2000.

After the sampling method was tested on the 2000 swan population and was shown to be reliable, it was used on the 2005 swan survey data to test if it could still accurately estimate the population using block counts not used in the creation of the strata. The blocks remained in the same stratum, and the same numbers of blocks were chosen from each stratum. This was repeated 100 times to get 100 population estimates, which were then compared to the actual population size determined from visual counts at that time. If the sampling method still proved to accurately estimate the population in 2005, it was then updated using the 2005 data to be used on the 2010 data. This was done by using one block selection run, chosen at random to update the number of swans in those blocks from the 2000 data. The 2010 swan population will only be estimated once because there were only 55 blocks surveyed in the survey area during 2010. This estimate could not be compared to the total swan population of the area during 2010 because the entire area was not surveyed. However it can be used as a probable population estimate for population trends of that area for the year. When this was finished, the 2000 data was fully updated with the 2005 data and the 2010 data where applicable to suggest future strata size if stratified sampling is to be used for Trumpeter Swan population estimates in the future. The block was given the highest count of the three sample years when assigning strata for future use.

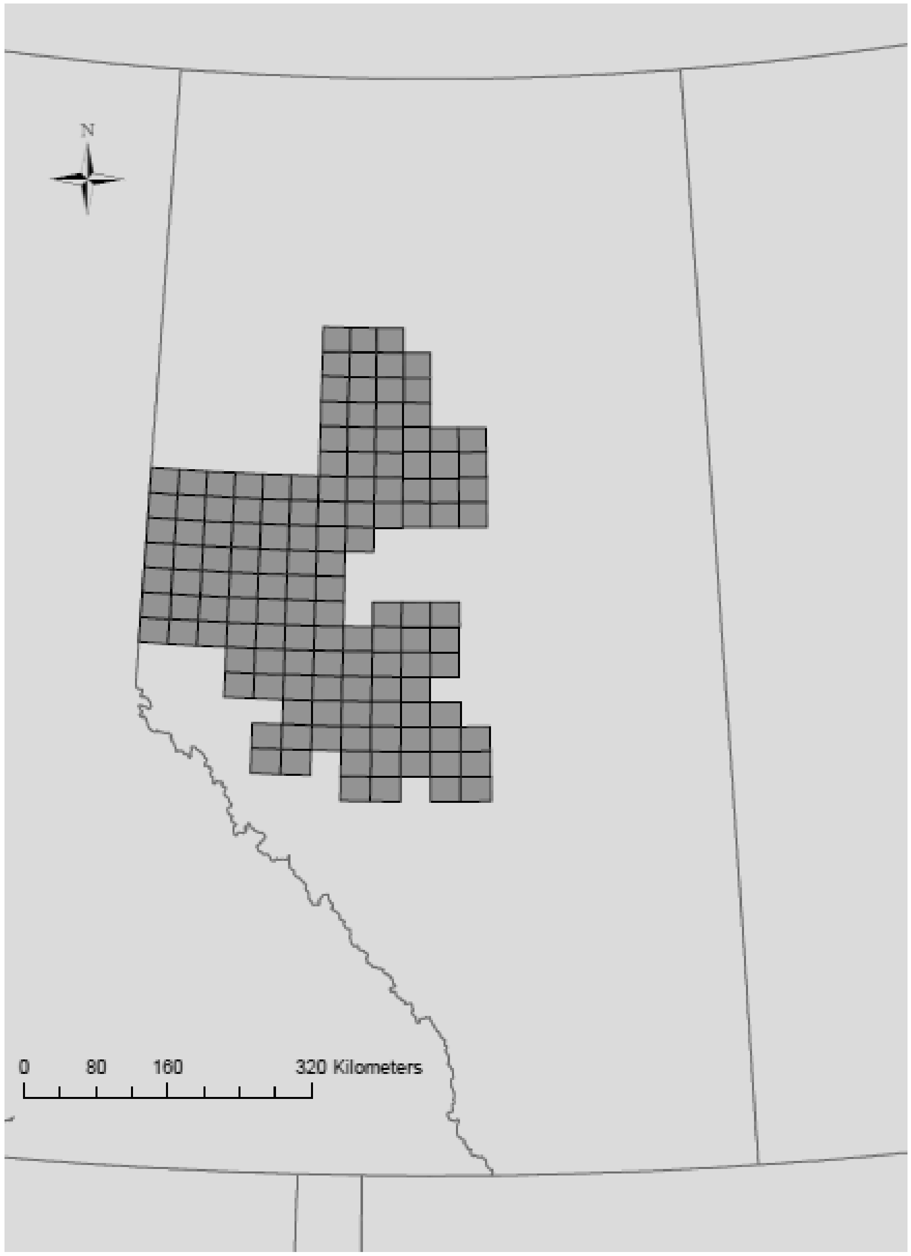

Figure 3.5 – Survey blocks for experiment.

3.3 RESULTS

After carefully examining the histogram for the 2000 survey data of swans per block, I decided to use 4 different strata (Figure 3.6). The numerical categories of blocks were set at 0 swans, 1-50 swans, 51-100 swans, and 101+ swans per block. There were clear breaks in the block count distribution at these points, and this categorization would also give managers easy break points to use. There was a total of 132 survey blocks in the survey area, 83 of which were in the 0 swan stratum, 44 in the 1-50 swan stratum, 4 in the 51-100 swan stratum, and 1 in the 101+ swan stratum. Using stratified random sampling with the goal of surveying 50% of the survey area, I surveyed 66 survey blocks, 30 in the 0 stratum, 31 in the 1-50 stratum, 4 in the 51-100 stratum, and 1 in the 101+ stratum. I found an average population estimate of 774±4 swans (Table 3.1) (Figure 3.7). The actual Trumpeter Swan population surveyed at that time was 775 swans.

For the 2005 survey I used the same strata and the same number of blocks surveyed in each. This gave me the average population estimate of 1229 ±9 swans (Table 3.1) (Figure 3.8). The actual swan population counted during this survey was 1231 swans. For the 2010 population estimate I updated 66 of the original 2000 swan per block count data used to create the strata with a randomly chosen sampling of the 2005 data. With this updated data I found the histogram of the swans per block to be similar to the 2000 data and decided to use the same strata (Figure 3.9). There were only 55 blocks surveyed during the 2010 Trumpeter Swan survey in this sample area, so I was unable to randomly choose

66 blocks. The one sample survey I could do for 2010 gave me an estimate of 3103 swans for the area (Table 3.1). Following this I updated the original 2000 swan per block counts with all the data from 2005 and 2010 (Figure 3.10).

Table 3.1 – Summary of population estimates using stratified random sampling and the actual surveyed populations for the designated area.

Year	**Population Estimate**	**Actual Population**
2000	774±4	775
2005	1229±9	1231
2010	3103	2329

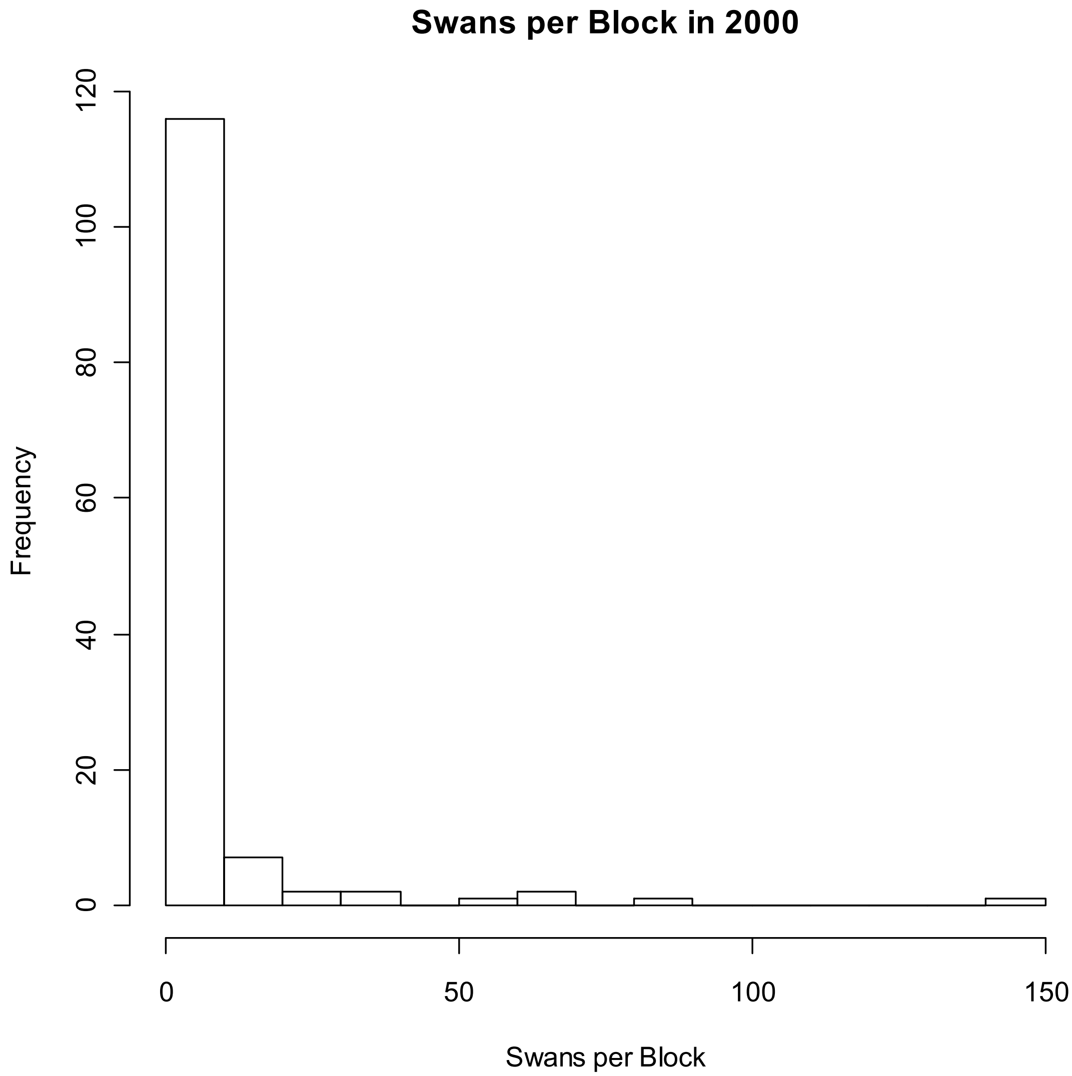

Figure 3.6 – The histogram of the 2000 swan survey of swans per block.

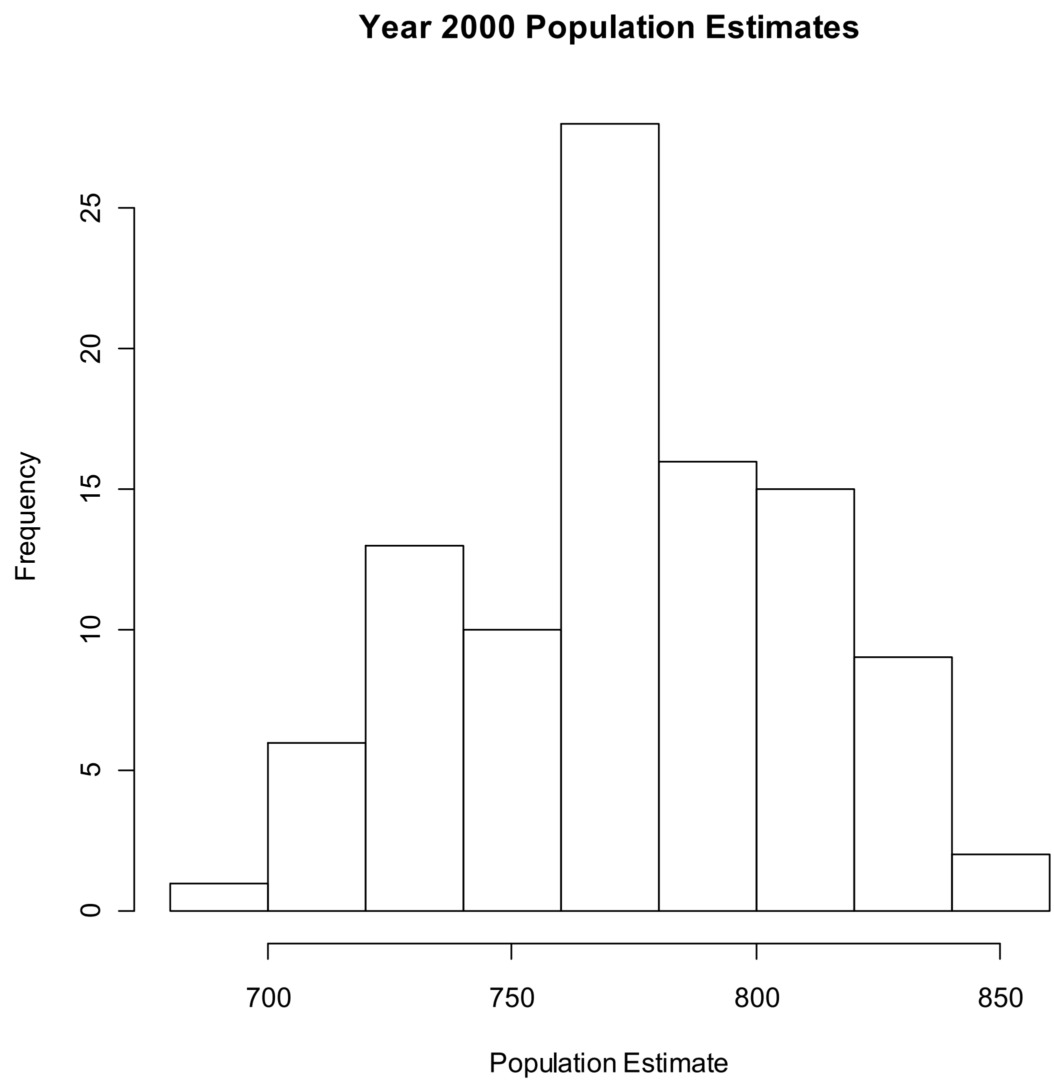

Figure 3.7 – The population estimates using stratified sampling for the year 2000. The average population estimate was 774±4 swans and the actual population was 775 swans.

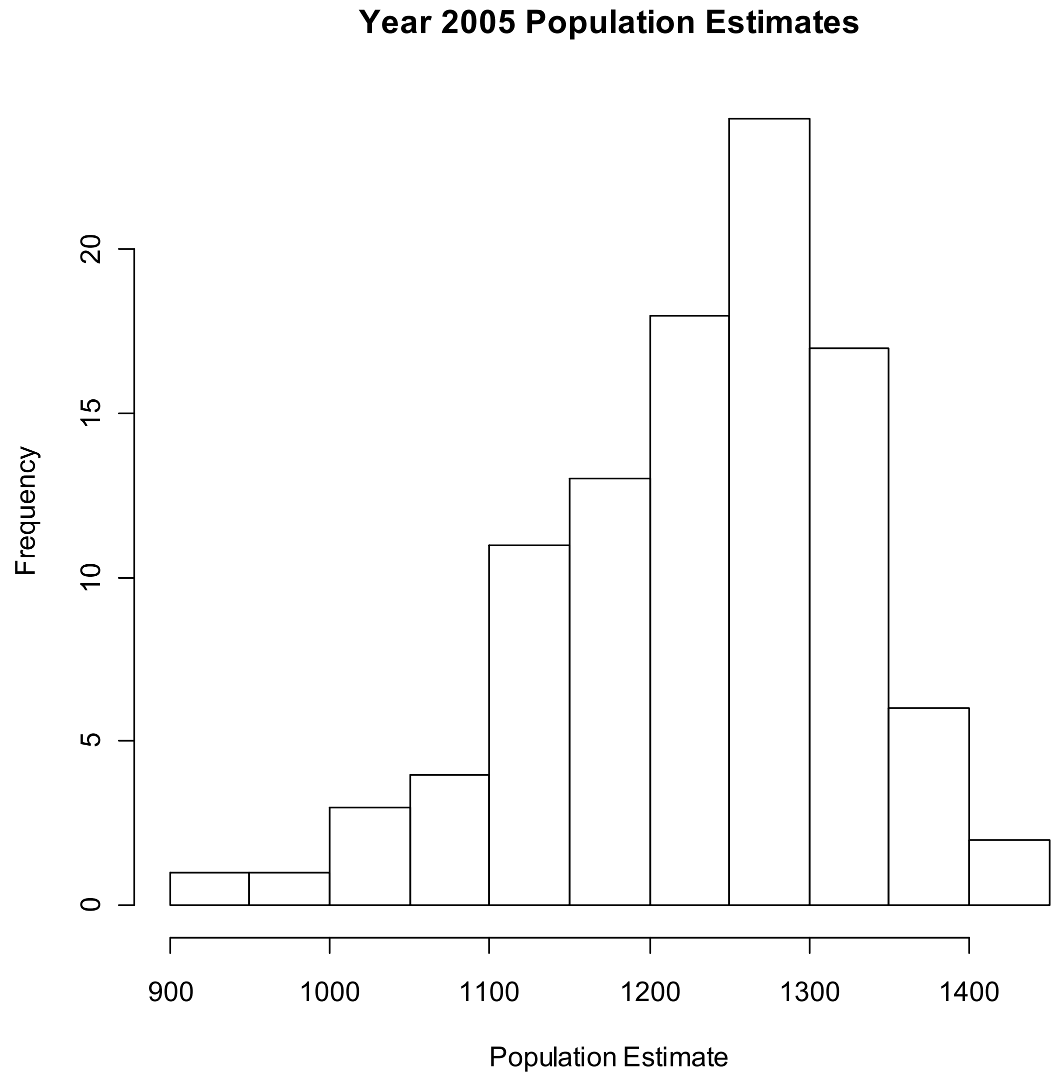

Figure 3.8 – Population estimates of the 2005 Trumpeter Swan population using stratified random sampling. The average estimate was 1229 ±9 swans and the actual population count was 1231 swans.

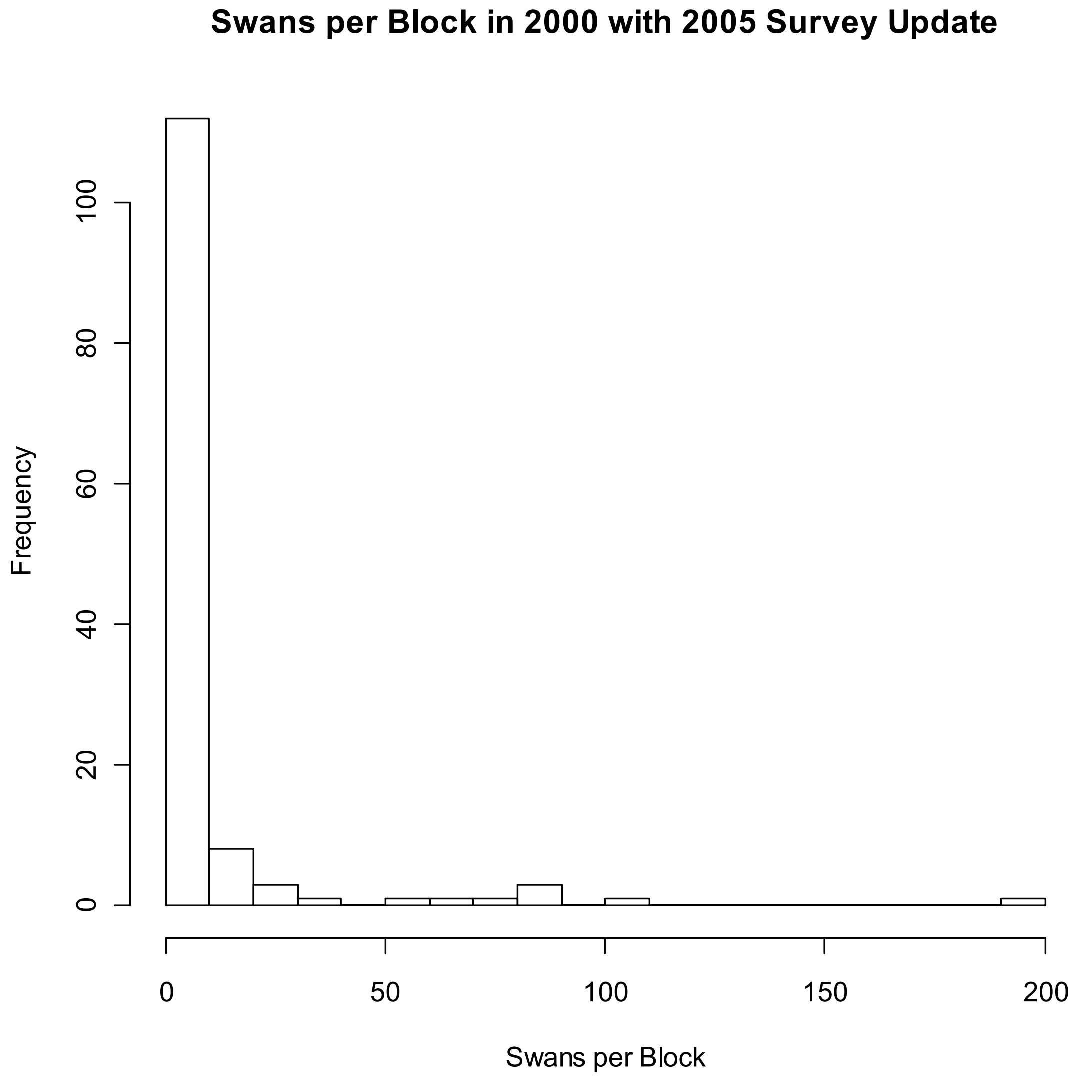

Figure 3.9 – The histogram of swans per block after updating the 2000 data with a sample survey of the 2005 data.

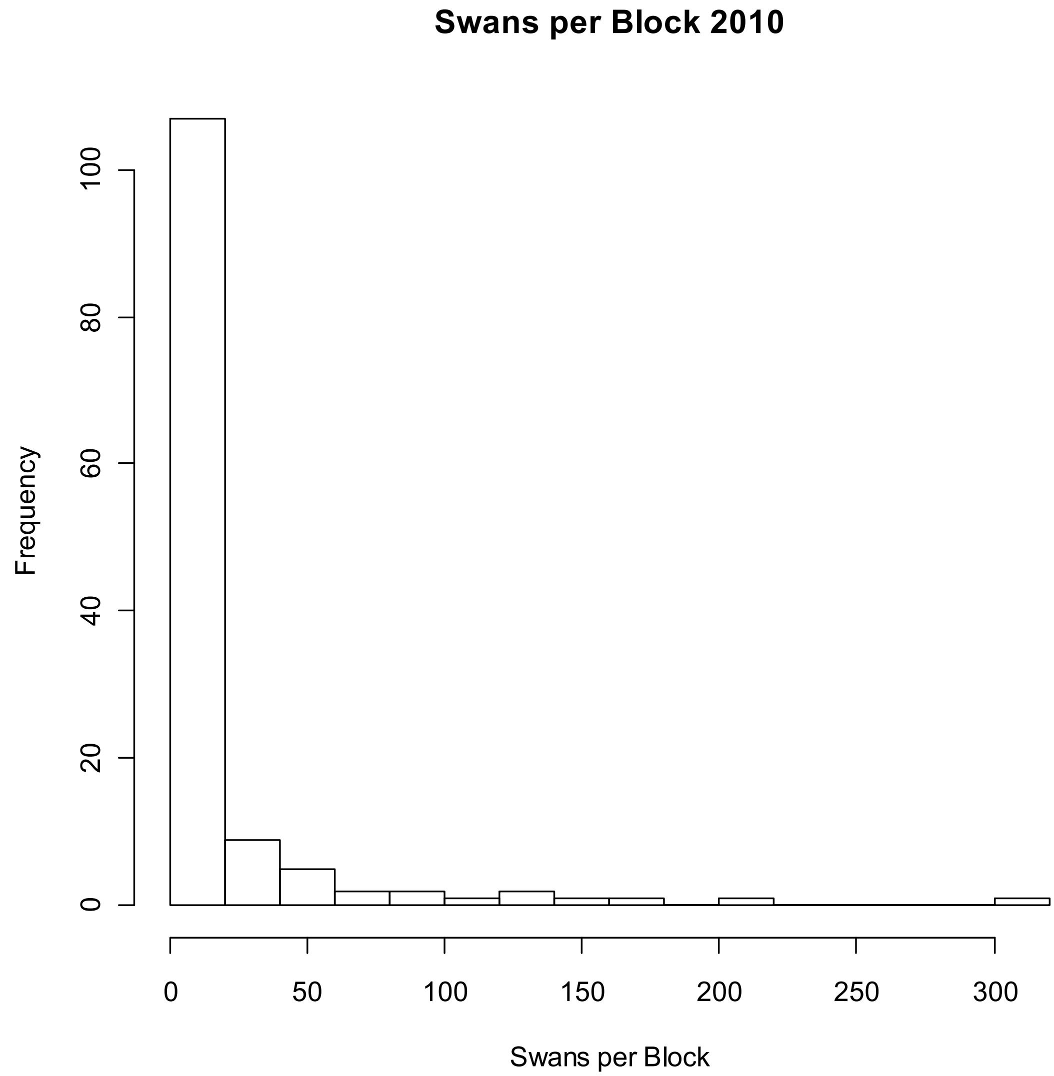

Figure 3.10 – The histogram of swans per block combining the highest block counts of 2000, 2005, and 2010 surveys.

3.4 DISCUSSION

I stratified random sampling accurately estimated the Trumpeter Swan Population for 2000 and 2005. It was important and noteworthy that the 2000 data were able to be used to create strata that accurately predicted the 2005 population showing that past surveys can still be used to define strata. However, Trumpeter Swan populations are still recovering and population growth is occurring, which means strata size and block allocation will have to be updated on an ongoing basis. Higher counts occurring in blocks between surveys indicate that habitat availability is not likely the limiting factor in many areas yet.

With the population increasing and expanding, the cost to survey it will continue to rise while the possible delisting of the species will reduce the demand for the frequency of surveys. By only surveying 50% of the entire survey area, survey costs may be greatly reduced for estimating full population numbers. This could be particularly effective on the fringes where expansion is slow and swan counts are low due to the infilling of empty suitable habitat in already established ranges. Swans do appear to pioneer the fringes of their range boundaries but infilling of available habitats is also likely to absorb many of the new pairs so populations can grow both expansively and through densification of occupancy.

The 2010 population estimate was not as accurate as the 2000 and 2005 estimates due to lower sampling effort. During the 2010 survey, stratified random sampling was attempted for the first time in Alberta. The survey area was broken into survey blocks and was assigned to strata used in other portions of Canada. These strata were not based on swan populations and densities in Alberta and did not sufficiently reduce the variation in block counts. However most of the blocks that were chosen to be surveyed in 2010 were not randomly chosen. Instead most were chosen to cover the areas of higher density of swans because financial limitations did not allow coverage of the entire area. This gave me only a limited number of blocks from which to estimate the population and biased the population estimate to be higher than the true numbers in the entire survey area by the selective elimination of blocks where biologist did not expect to find large numbers of swans.

For future surveys I would keep the same strata I used to estimate swan populations here. Looking at the histogram of the updated 2010 data (Figure 3.10), there are more blocks falling into the highest count stratum with increased population growth, but not enough to redesign the strata size. Swan populations will continue to increase before stabilizing in blocks as long as there is suitable nesting habitat for swans. This may already have happened in some of the higher count blocks in the Grande Prairie area. The highest count blocks are currently blocks were migration staging lakes such as Bear and Saskatoon Lakes and for which all swans in the region are aware of as potential breeding lakes. It is important to have these blocks in a separate stratum to ensure coverage of these blocks with such a large portion of the population staging there every year. It is the ability to separate out these extremely high count blocks from the low expansion blocks with only pioneer pairs residing in them that reduces the variation in strata and allows for accurate population estimates using stratified random sampling.

3.5 REFERENCES

Beyersbergen, G.W. Regional Coordinator/Editor. 2007. The 2005 International Trumpeter Swan Survey in Alberta, Saskatchewan, Manitoba and the Northwest Territories. Canadian Wildlife Service Technical Report Series No. 485. Prairie and Northern Region. Edmonton, Alberta. 45 pp.

Cochran, W.G. 1977. Sampling techniques. Third ed. John Wiley and Sons, New York, N.Y. 428 pp.

Contant, B.H., J.I. Hodges, D.J. Groves, and J.G. King. 2002. Census of Trumpeter Swans on Alaskan nesting habitats, 1968-2000. Pages 3-7 *in* Proceedings of the Fourth International Swan Symposium, 2001 (E.C. Rees, S.L. Earnst, and J. Coulson, Eds.). Waterbirds 25, Special Publication 1.

Contant, B.H., J.I. Hodges, and J.G. King. 1991. Continuity and advancement of Trumpeter Swan *Cygnus buccinators* and Tundra Swan *Cygnus columbianus* population monitoring in Alaska. Pages 125-136 *in* Proceedings Third IWRB International Swan Symposium (J. Sears and P.J. Bacon, Eds.). Wildfowl Supplement, Number 1.

Hawkings, J.S. 2000. Design and effectiveness of the 1995 Yukon/northern British Columbia swan survey: an appropriate technique for 2000 and beyond? Pages 145-153 *in* Proceedings and Papers of the Seventeenth Trumpeter Swan Society Conference-Trumpeter Swans: a secure future? (R.E. Shea, M.H. Linck and H.K. Nelson, Eds.). North American Swans 29(1).

Hawkings, J.S., A. Breault, S. Boyd, M. Norton, G. Beyersbergen, and P. Latour. 2002. Trumpeter Swan numbers and distribution in western Canada, 1970-2000. *Waterbirds* 25: 8-21.

Mackay, R.H. 1981. The Trumpeter Swan-an endangered species in Canada. Pp. 22-23 *in* Proceedings and Papers of the Sixth Trumpeter Swan Society Conference. Trumpeter Swan Society, Maple Plain, MN.

Moser, T.J. 2006. The 2005 North American Trumpeter Swan Survey. United States Fish and Wildlife Service. 23 pp.

Reed, A., H. Boyd, P. Chagnon, and J. Hawkings. 1995. The numbers and distribution of Greater Snow Geese on Bylot Island and near Jungersen Bay, Baffin Island, in 1988 and 1983. *Artic* 45: 115-119.

Reed, A. and P. Chagnon. 1987. Greater Snow Geese on Bylot Island, Northwest Territories, 1983. *Journal of Wildlife Management* 51: 128-131.

Snedecor, G.W. and W.G. Cochran. 1989. Statistical Methods. Eighth Ed. Iowa State University Press, Ames, Iowa. 503 pp.

4 Management Implications

I would advise wildlife managers to keep buffer zones around swan nesting lakes. Even though human disturbance on the landscape only produced three significant models with my research, I feel it is not capturing the whole picture. The power line model's variable of distance to power line did have a positive relationship with cygnet count. Power lines have already been identified as a threat to Trumpeter Swans from collisions, but may also be indirectly affecting nesting success. With the disturbance experiment there is evidence that when Trumpeter Swans view human presence it can elicit a disturbance response from a distance. This should also be taken into consideration when landscape planning, in that visual barriers around swan nesting lakes are important for maintaining the isolation and quality of nesting lakes.

I would also recommend the use of stratified random sampling if a Total Minimum Population count is not achievable under conditions of expanding swan population numbers and range. The stratified random sample performed well when sampling the 2000 and 2005 populations. It is important though to randomly select the units being surveyed and have adequate strata division to lower variation in each stratum from the entire sample unit. This method will also be helpful in setting designated survey areas so survey effort can be easily measured and controlled between years to ensure consistency.

If Trumpeter Swan populations continue to increase, the eventual delisting of this species is inevitable. However, I do not think that the Alberta population is ready to lose its protection yet. While some of the northern populations in the Peace River area may continue to grow with low human population and disturbance in the area, most areas such as the Grande Prairie area, where a majority of the population reside, with extensive oil and gas activities on the crown land will slow or stop population growth. If swan sub-populations continue to expand into new areas where human activity on crown land is limited and growth and stability continues in sub-populations habituated to nesting in agricultural areas, I believe delisting will be possible without further protection.

5 Bibliography

Alberta Trumpeter Swan Recovery Team. 2006. Alberta Trumpeter Swan Recovery Plan, 2005-2010. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Recovery Plan No. 12. Edmonton, AB.

Banko, W.E. 1960. The Trumpeter Swan. North American Fauna No. 63, U.S. Fish and Wildlife Service, Washington, DC.

Bellrose, F.C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

Beyersbergen, G.W. Regional Coordinator/Editor. 2007. The 2005 International Trumpeter Swan Survey in Alberta, Saskatchewan, Manitoba and the Northwest Territories. Canadian Wildlife Service Technical Report Series No. 485. Prairie and Northern Region. Edmonton, Alberta. 45 pp.

Boudreau, G.W. 1968. Alarm sounds and responses of birds and their application in controlling problem species. *Living Birds* 7: 27-46.

Burton, N.H.K., M.J.S. Armitage, A.J. Musgrove, and M.M. Rehfisch. 2002a. Impacts of man-made landscape features on numbers of estuarine waterbirds at low tide. Environmental Management 30: 857-864.

Burton, N.H.K., M.M. Rehfisch, and N.A. Clark. 2002b. Impacts of disturbance from construction work on the densities and feeding behavior of waterbirds using the intertidal mudflats of Cardiff Bay, UK. Environmental Management 30: 865-871.

Cochran, W.G. 1977. Sampling techniques. Third ed. John Wiley and Sons, New York, N.Y. 428 pp.

Conomy, J.T., J.A. Dubovsky, J.A. Collazo, and W.J. Fleming. 1998. Do Black Ducks and Wood Ducks habituate to aircraft disturbance? *Journal of Wildlife Management* 62: 1135-1142.

Contant, B.H., J.I. Hodges, D.J. Groves, and J.G. King. 2002. Census of Trumpeter Swans on Alaskan nesting habitats, 1968-2000. Pages 3-7 *in* Proceedings of the Fourth International Swan Symposium, 2001 (E.C.

Rees, S.L. Earnst, and J. Coulson, Eds.). Waterbirds 25, Special Publication 1.

Contant, B.H., J.I. Hodges, and J.G. King. 1991. Continuity and advancement of Trumpeter Swan *Cygnus buccinators* and Tundra Swan *Cygnus columbianus* population monitoring in Alaska. Pages 125-136 *in* Proceedings Third IWRB International Swan Symposium (J. Sears and P.J. Bacon, Eds.). Wildfowl Supplement, Number 1.

Corace III, R.G., D.L. McCormick, and V. Cavalieri. 2006. Population growth parameters of a reintroduced trumpeter swan flock, Seney National Wildlife Refuge, Michigan, USA (1991-2004). *Waterbirds* 29: 38-42.

Dingemanse, N.J., C. Both, P.J. Drent, and J.M. Tinbergen. 2004. Fitness consequences of avian personalities in a fluctuating environment. *Proceedings of the Royal Society of London Series B-Biological Sciences* 271: 847-852.

Fish and Wildlife Division. 2004. Report of Alberta's Endangered Species Conservation Committee: June 2002. Alberta Sustainable Resource Development, Fish and Wildlife Division, Edmonton, AB.

Groves, D.J. 2012. The 2010 North American trumpeter swan survey. U.S. Fish and Wildlife Service, Division of Migratory Bird Management, Juneau, Alaska, USA.

Hawkings, J.S. 2000. Design and effectiveness of the 1995 Yukon/northern British Columbia swan survey: an appropriate technique for 2000 and beyond? Pages 145-153 *in* Proceedings and Papers of the Seventeenth Trumpeter Swan Society Conference-Trumpeter Swans: a secure future? (R.E. Shea, M.H. Linck and H.K. Nelson, Eds.). North American Swans 29(1).

Hawkings, J.S., A. Breault, S. Boyd, M. Norton, G. Beyersbergen, and P. Latour. 2002. Trumpeter Swan numbers and distribution in western Canada, 1970-2000. *Waterbirds* 25: 8-21.

Henson P. and J.A. Cooper. 1993. Trumpeter Swan incubation in areas of differing food quality. *Journal of Wildlife Management* 57: 709-716.

Henson, P. and T.A. Grant. 1991. The effects of human disturbance on Trumpeter Swan breeding behavior. *Wildlife Society Bulletin* 19: 248-257.

Holton, G. 1982. Habitat use by trumpeter swans in the Grande Prairie region of Alberta. Thesis, University of Calgary, Calgary, Canada.

James, M.L. 2000. Status of Trumpeter Swan (Cygnus buccinator) in Alberta. Alberta Environment, Fisheries and Wildlife Management Division, and Alberta Conservation Association, Wildlife Status Report No. 26, Edmonton, AB.

Keller, V.E. 1991. The effect of disturbance from roads on the distribution of feeding sites of geese (*Anser brachyrhynchus, A. anser*), wintering in north-east Scotland. *Ardea* 79: 229-232.

Klein, M.L., S.R. Humphrey, and F. Percival. 1995. Effects of ecotourism on distribution of waterbirds in a wildlife refuge. *Conservation Biology* 9: 1454-1465.

LaMontagne, J.M., L.J. Jackson, and R.M.R. Barclay. 2003. Characteristics of ponds used by trumpeter swans in a spring migration stopover area. *Canadian Journal of Zoology* 81: 1791-1798.

Mackay, R.H. 1981. The Trumpeter Swan-an endangered species in Canada. Pp. 22-23 *in* Proceedings and Papers of the Sixth Trumpeter Swan Society Conference. Trumpeter Swan Society, Maple Plain, MN.

Milsom, T.P., D.C. Ennis, D.J. Haskell, S.D. Langton, and H.V. McKay. 1998. Design of grassland feeding areas for waders during winter: the relative importance of sward, landscape factors and human disturbance. *Biological Conservation* 84: 119-129.

Mitchell, C.D. 1994. Trumpeter swan (*Cygnus buccinator*): The birds of North America. The Academy of Natural Sciences, Philadelphia, Pennsylvania, USA and The American Ornithologists' Union Number 105, Washington, D.C., USA.

Monda, M.J., J.T. Ratti, and T.R. McCabe. 1994. Reproductive ecology of Tundra Swans on the Arctic National Wildlife Refuge, Alaska. *Journal of Wildlife Management* 58: 757-773.

Mori, Y., N.S. Sodhi, S. Kawanishi, and S. Yamagishi. 2001. The effect of human disturbance and flock composition on the flight distance of waterfowl species. *Journal of Ethology* 19: 115-119.

Moser, T.J. 2006. The 2005 North American Trumpeter Swan Survey. United States Fish and Wildlife Service. 23 pp.

Natural Regions Committee 2006. Natural Regions and Subregions of Alberta. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. T/852.

Newton, I. 1977. Timing and success of breeding in tundra nesting geese. Pages 113-126 *in* B. Stonehouse and C.M. Perrins, eds. Evolutionary Ecology. Macmillan Publishing, London, U.K.

Page, R.D. 1974. The ecology of the trumpeter swan on Red Rock Lakes National Wildlife Refuge, Montana. Final Report, U.S. Fish and Wildlife Service, Region 1.

Pease, M.L., R.K. Rose, and M.J. Butler. 2005. Effects of human disturbances on the behavior of wintering ducks. *Wildlife Society Bulletin* 33: 103-112.

Proffitt, K.M., T.P. McEneaney, P.J. White, and R.A. Garrott. 2010. Productivity and fledging success of trumpeter swans in Yellowstone National Park, 1987-2007. *Waterbirds* 33: 341-348.

Reed, A., H. Boyd, P. Chagnon, and J. Hawkings. 1995. The numbers and distribution of Greater Snow Geese on Bylot Island and near Jungersen Bay, Baffin Island, in 1988 and 1983. *Artic* 45: 115-119.

Reed, A. and P. Chagnon. 1987. Greater Snow Geese on Bylot Island, Northwest Territories, 1983. *Journal of Wildlife Management* 51: 128-131.

Snedecor, G.W. and W.G. Cochran. 1989. Statistical Methods. Eighth Ed. Iowa State University Press, Ames, Iowa. 503 pp.

Schmidt, J.H., M.S. Lindberg, D.S. Johnson, and J.A. Schmutz. 2009. Environmental and human influences on Trumpeter Swan habitat occupancy in Alaska. The Condor 111: 266-275.

6 Appendix

Appendix A: These are the results collected during the disturbance experiment conducted in 2011. A total of 19 pairs were approached by a pedestrian disturber.

Waterbody	UTM Zone	Easting	Northing	Date	Birds	Conditions	Behavior	End (m)	Behavior
Lowe Lake	11N	361950	6133100	3-Sep	2+5	Sunny, Breezy, midday	alerted to eagle, heads up	526	heads up, moving away
Economy Fire Tower - East	11N	416500	6071400	6-Sep	2+0	partly cloudy, midday	Feeding	720	heads up, moving away
Economy Fire Tower - South	11N	420950	6069400	6-Sep	2+1	partly cloudy, midday	napping on nest	628	heads up, moving away
Economy Creek 11	11N	418250	6091550	6-Sep	2+5	Partly cloudy, afternoon	Feeding	738	heads up, moving away
Anderson Lake	11N	357650	6134600	10-Sep	2+3	Sunny, Breezy, midday	Feeding	998	heads up, moving away
Anderson Lake	11N	357650	6134600	10-Sep	2+6	Sunny, Breezy, midday	Resting in middle	903	heads up, moving away
Valhalla	11N	344750	6139550	10-Sep	2+3	Sunny, Breezy, afternoon	Feeding	605	heads up, moving away
Martin Lake	11N	336000	6146650	10-Sep	2+0	Sunny, Breezy, afternoon	Feeding	614	heads up, moving away
Brainard/Sinclair Lake	11N	326000	6142000	10-Sep	2+1	Sunny, no wind, afternoon	Feeding	730	heads up, moving away
Powell	11N	322100	6140500	10-Sep	2+5	partly cloudy, no breeze, evening	Feeding	680	one adult flew at me, other escorted cygnets heads up away
Wood Lake	11N	390100	6113200	11-Sep	2+0	mostly cloudy, breezy, midday	resting in weeds	545	swam out, heads up
Saskatoon	11N	366350	6121025	12-Sep	2+0	mostly cloudy, breezy, afternoon	Feeding	736	swam away
Little Lake	11N	367150	6118750	12-Sep	2+4	mostly cloudy, evening	Feeding	453	heads up, moving away
Flyingshot Lake	11N	381500	6111800	13-Sep	2+2	cloudy, windy, midday	Feeding	1179	heads up, moving away
McNaught Lake	11N	344000	6113550	13-Sep	2+5	partly cloudy, afternoon, windy	Feeding	416	heads up, moving away
Goodfare Lake	11N	329250	6128250	13-Sep	2+3	windy, partly sunny, afternoon	feeding, alert to eagle, feeding	840	heads up, moving away
Driftwood	11N	323700	6124750	13-Sep	2+5	mostly cloudy, windy, afternoon	swimming	1015	one adult flew at me, other escorted cygnets heads up away
Kamisak Lake	11N	324950	6116200	13-Sep	2+1	cloudy, windy, evening	swimming	749	heads up, moving away
Kamisak Lake	11N	324950	6116200	13-Sep	2+0	cloudy, windy, evening	swimming	904	heads up, moving away

Appendix B: Trumpeter Swan survey data collected from the 2000 Trumpeter Swan Continental Breeding survey provided by Alberta Sustainable Resource and Development Fish and Wildlife department. This data was used for the analysis of swan productivity in relation to human disturbance.

Name	Zone	Easting	Northing	Adult	Cygnets	Area (ha)	Well site	Oil	Road	Railway	Powerline	Pipeline	Green Zone	White Zone
Albright Lake	11N	322000	6152700	2	5	308	338	1169	56	5071	25024	452	1	0
Anderson Lake	11N	357650	6134600	2	7	138	409	359	55	17215	355	149	0	1
Barr Creek 3	11N	319100	6122600	2	1	17	260	2056	117	14335	12451	121	0	1
Bisbing Lake	11N	332250	6126450	2	5	30	680	779	98	7755	783	186	0	1
Boone 3	11N	345858	6172775	2	2	0	419	1080	330	37292	6352	337	1	0
Boone Lake - North	11N	353100	6171000	2	3	175	211	314	288	32712	6924	287	1	0
Boone Lake - West 4	11N	331200	6160400	2	1	5	733	1742	427	17818	25269	236	1	0
Buffalo Lake - West	11N	373000	6138450	2	5	36	274	2385	17	12710	3344	585	0	1
Calahoo Creek 1 (Calahoo Lake)	11N	310275	6082650	2	3	51	1510	3005	297	50871	29358	757	1	0
Calahoo Creek 4	11N	333400	6087550	2	3	103	606	476	516	31834	14704	70	1	0
Cattail Lake	11N	455400	6134000	2	1	40	758	7123	1417	48799	21575	3149	1	0
Chain Lake - Northeast	11N	315850	6144450	2	5	15	742	778	536	3064	23294	363	1	0
Chain Lake - Southwest	11N	314200	6143150	2	5	19	494	504	507	4078	23547	194	1	0
Clairmont Lake	11N	388650	6123750	1	1	674	36	0	11	220	11	70	0	1
Cutbank Lake 2 (North)	11N	326750	6177950	2	1	64	73	0	4	10130	8868	0	0	1
Dickson Lake	11N	319050	6155650	2	3	38	278	1669	51	5858	29722	575	1	0
Dorscheid	11N	403300	6070600	2	3								1	0
Economy Creek 4	11N	427100	6085450	2	6	86	2030	12420	4823	28252	2021	2526	1	0
Ellenwood Lake	11N	417100	6096350	2	4	105	699	1000	1785	14145	12392	314	1	0
Flyingshot Lake	11N	381500	6111800	2	6	158	444	1229	37	165	527	194	0	1
Fowel Lake - North	11N	330300	6120650	2	4	0	522	560	386	12633	1558	425	0	1
Goodfare Lake - West	11N	323500	6131650	2	2	37	531	924	534	4706	10390	236	0	1
Grassy Lake - West	11N	460550	6073800	2	4	27	484	588	469	50320	11135	450	1	0
Hamelin Creek	11N	349500	6202050	2	1								1	0
Hermit Lake	11N	375000	6119000	2	6	298	594	721	24	5365	6122	243	0	1
Horse Lake	11N	328000	6135300	2	3	0	179	300	59	5	7297	153	0	1
Jack Bird Pond	11N	364150	6193000	2	4	6	215	1137	0	22227	12367	543	0	1

Name	Zone	Easting	Northing	Adult	Cygnets	Area (ha)	Well site	Oil	Road	Railway	Powerline	Pipeline	Green Zone	White Zone
Kamisak Lake	11N	324950	6116200	2	5	203	351	2918	560	17908	6450	568	0	1
Kamisak Lake - South	11N	326000	6114700	2	2	18	487	2548	529	21111	6955	459	0	1
Keeping Lake	11N	314450	6149800	2	2	19	793	658	573	51	27695	869	0	1
Latornell River 2	11N	434700	6073800	2	5	15	1332	2775	2355	26023	9278	2294	1	0
Long Lake	11N	463500	6082900	2	4	274	679	927	474	21621	80	258	1	0
Lowe Lake	11N	361950	6133100	2	3	35	110	35	108	17077	1631	15	0	1
Moose Lake	11N	474700	6071700	2	4	67	157	1641	679	62554	4980	1560	0	1
Mountain Lake	11N	455100	6144800	2	2	16	690	3926	891	37923	30477	1055	1	0
Mt. Valley 2	11N	314150	6112300	2	1	26	633	1075	391	25890	17217	2	0	1
Mt. Valley 6 (NW Mt. Valley 2)	11N	317550	6112100	2	5	29	517	981	612	24804	13884	567	0	1
Mt. Valley 7	11N	312300	6113200	2	1	4	491	698	153	25963	18698	428	0	1
Pelican Lake	11N	457300	6098100	2	2	95	1310	2650	233	53272	5338	206	1	0
Pelican Lake 1	11N	452200	6100100	2	3	36	1010	1884	1720	48742	5383	454	0	1
Pelican Lake 2	11N	450150	6099600	2	5	41	2372	3456	1923	46573	7369	859	0	1
Ponita Lake	11N	320650	6154850	2	5	73	542	772	608	6715	28150	394	1	0
Puskwaskau 2	11N	458400	6116100	2	3	86	1538	4028	2441	56398	10006	3454	1	0
Ray Lake	11N	317800	6146700	2	2	133	660	907	22	5	22573	921	0	1
Simonette River 10 (Side Lake)	11N	441200	6079500	2	5	120	452	649	4034	34265	3557	340	1	0
Simonette River 12	11N	443800	6069600	2	5	43	707	5047	204	32984	14224	5421	1	0
Simonette River 13 (Jackfish Lake)	11N	439850	6066450	2	1	138	429	465	365	22512	16873	584	1	0
Simonette River 2	11N	448000	6089400	2	4	8	1307	4289	1454	46128	4718	1810	0	1
Simonette River 7	11N	453600	6080600	2	1	33	1266	2726	467	46192	3495	1778	1	0
Simonette River 9	11N	442900	6081300	2	6	36	570	827	3982	37104	2696	640	1	0
Sinclair Lake (Brainard Lake)	11N	326000	6142000	2	5	360	194	232	21	4040	13718	244	0	1
Smoky River 18	11N	406900	6094600	2	4	14	1555	4064	3482	6722	8436	3438	1	0
Two Lakes - South	11N	454350	6128300	2	2	51	11	3320	4	52936	16570	1560	1	0
Wabatanisk Creek 2	11N	459250	6128600	2	2	20	2163	7682	5204	54547	20627	3490	1	0
Water Hen Lake 3	11N	450100	6140650	2	3	18	4494	7244	5236	41499	24245	3527	1	0
Water Hen Lake 4	11N	453350	6140100	2	5	7	2159	8169	5147	42865	25505	357	1	0
Whitham Lake	11N	328200	6144300	2	5	205	393	623	268	7502	15110	284	0	1
Windsor Creek 2	11N	314400	6115300	2	3	2	426	1421	139	23630	17621	360	0	1
Wolfe Lake	11N	361450	6144800	1	1	103	435	313	149	24897	5029	301	0	1

Name	Zone	Easting	Northing	Adult	Cygnets	Area (ha)	Well site	Oil	Road	Railway	Powerline	Pipeline	Green Zone	White Zone
Yoke Lake	11N	330250	6122100	2	4	60	214	513	85	11476	1822	110	0	1

Appendix C: Trumpeter Swan survey data collected from the 2005 Trumpeter Swan Continental Breeding survey provided by Alberta Sustainable Resource and Development Fish and Wildlife department. This data was used for the analysis of swan productivity in relation to human disturbance.

Name	Zone	Easting	Northing	Adult	Cygnets	Area (ha)	Well site	Oil	Road	Railway	Powerline	Pipeline	Green Zone	White Zone
Albright Lake	11N	322000	6152700	2	1	308	338	1169	56	5071	25024	452	1	0
Anderson Lake	11N	357650	6134600	2	5	138	409	359	55	17215	355	149	0	1
Bethel Lake	11N	313650	6166200	2	3	58	108	1936	476	13204	36811	894	1	0
Boone Creek	11N	338850	6159800	2	1	18	257	234	213	23773	20765	228	1	0
Boone Lake - North	11N	353100	6171000	2	2	175	211	314	288	32712	6924	287	1	0
Canon Smith Lake	11N	371900	6115950	2	2	21	408	431	152	2845	3590	72	0	1
Cattail Lake - South	11N	455700	6132800	2	1	3	1520	6784	2076	50315	20765	4641	1	0
Chain Lake - Central	11N	315000	6143700	2	4	7	494	504	507	4078	23547	194	1	0
Dickson Lake	11N	319050	6155650	2	3	38	278	1669	51	5858	29722	575	1	0
Dimsdale Lake	11N	372400	6113600	2	5	64	877	829	142	212	816	691	0	1
Dorscheid	11N	403300	6070600	2	3								1	0
Driftwood Marsh (Ducks Unlimited)	11N	323700	6124750	2	2	50	388	686	119	10678	8809	469	0	1
Dune's project #1	11N	406940	6113558	2	2	151	532	470	68	10210	7650	454	0	1
Dune's project #2	11N	407585	6112828	2	4	151	347	130	28	10028	7469	235	0	1
Economy Creek 1	11N	417100	6087875	2	4	15	568	6276	1998	18708	4794	550	1	0
Economy Creek 10 (Tyke Lake)	11N	419600	6090700	2	1	51	715	3451	42	19069	7343	767	1	0
Economy Creek 11	11N	418250	6091550	2	4	60	1648	3040	1376	18266	8447	1200	1	0
Economy Creek 6 (East Dietz Lake)	11N	429750	6086400	2	5	130	1298	10145	7133	29529	3030	3069	1	0
Ellenwood Lake	11N	417100	6096350	2	4	105	699	1000	1785	14145	12392	314	1	0
Elmworth East	11N	335265.96	6102416.64	2	2	22	500	639	27	19404	2878	128	0	1
Ferguson Lake	11N	384700	6126000	2	3	253	1401	2018	250	1188	4553	787	0	1
Flyingshot Lake - W marsh	11N	380367.87	6113619.9	2	2	169	437	881	0	128	630	48	0	1
Fowel Lake	11N	331100	6119450	2	1	29	225	1074	129	12270	452	578	0	1
Goodfare Lake - West	11N	323500	6131650	2	1	38	531	924	534	4706	10390	236	0	1
Goose Creek 1	11N	466500	6088900	2	2	4	1339	6391	4131	61817	2714	279	1	0
Goose Lake - North corner	11N	464905.5	6093145.11	2	2	361	2998	3319	3814	60150	4230	2173	1	0

Name	Zone	Easting	Northing	Adult	Cygnets	Area (ha)	Well site	Oil	Road	Railway	Powerline	Pipeline	Green Zone	White Zone
Goose Lake - SE corner	11N	465654.86	6091388.98	2	4	361	2998	3319	3814	60150	4230	2173	1	0
Goose Lake - SW corner2	11N	462723.05	6091531.21	2	5	361	2998	3319	3814	60150	4230	2173	1	0
Grassy Lake	11N	462000	6075550	2	2	13	630	871	1310	52277	10113	691	1	0
Hermit Lake	11N	375000	6119000	2	3	220	594	721	24	5365	6122	243	0	1
Hughes Lake	11N	378350	6118300	2	7	96	416	857	23	4975	5664	41	0	1
Intermittent (Hudz)	11N	377400	6134650	2	3	104	229	1415	7	8183	545	101	0	1
Jackfish Lake North	11N	336907.15	6164566.28	2	4	7	209	645	29	25031	18105	129	1	0
Kakut Lake	11N	403900	6165500	2	4	371	106	303	24	9348	9752	225	0	1
Kamisak Lake	11N	324950	6116200	2	2	203	351	2918	560	17908	6450	568	0	1
Kamisak Lake 6	11N	321100	6114000	2	2	33	506	473	64	22008	9021	136	0	1
Latornell River 2	11N	434700	6073800	2	5	15	1332	2775	2355	26023	9278	2294	1	0
Little Lake	11N	367150	6118750	2	4	132	247	1660	61	5247	6038	223	0	1
Long Lake - creek south	11N	462054.41	6081371	2	6	21	920	1866	1289	54503	5123	1231	1	0
Lowe Lake	11N	361950	6133100	2	2	35	110	35	108	17077	1631	15	0	1
Lowen Lake	11N	332900	6119700	2	4	12	350	240	444	10993	848	433	0	1
McNaught Lake	11N	344000	6113550	2	3	32	331	3584	81	5143	66	185	0	1
Moose Lake	11N	474700	6071700	2	1	67	157	1641	679	62554	4980	1560	0	1
Mt. Valley 5	11N	319000	6112800	2	6	39	396	966	0	23556	12663	469	0	1
Mt. Valley 5a	11N	317667	6112255	2	5	29	517	981	612	24804	13884	567	0	1
No Name 102	11N	452114.11	6137925.88	2	3	7	3817	7927	6498	44348	23097	2541	1	0
No Name 104	11N	447577.74	6139427.1	2	4	3	4268	7387	6762	42794	22431	3237	1	0
No Name 106	11N	447429.5	6142720.41	2	3	35	1728	6748	3483	39571	24924	3554	1	0
No Name 107	11N	451576.41	6141915.21	2	4		4904	6097	4129	40741	26246	1893	1	0
No Name 112	11N	461621.84	6151734.62	2	4	2	1372	4937	1976	32186	29081	2195	0	1
No Name 117	11N	447001	6195364	2	3	128	0	1278	1075	12014	42038	0	0	1
No Name 18	11N	316952.27	6145111.88	2	1	6	473	1836	6	2568	22775	184	0	1
No Name 22	11N	331471.7	6121452.46	1	1	9	486	610	496	10931	249	100	0	1
No Name 43	11N	407142.03	6094494.37	2	4	14	1555	4064	3482	6722	8436	3438	1	0

Name	Zone	Easting	Northing	Adult	Cygnets	Area (ha)	Well site	Oil	Road	Railway	Powerline	Pipeline	Green Zone	White Zone
No Name 44	11N	409353.75	6085615.17	2	3	1	2022	4111	3616	13844	1585	929	1	0
No Name 51	11N	425440.3	6085694.07	2	1	4	1346	11328	3252	26912	2778	3759	1	0
No Name 52	11N	426157.11	6087093.08	2	3		1523	11434	4411	27369	3959	4777	1	0
No Name 60	11N	419354.78	6103040.29	2	2	15	2657	4286	1826	16013	15762	4083	1	0
No Name 62	11N	418645.31	6099231.14	2	2	14	909	2818	2204	14961	16170	2058	1	0
No Name 64	11N	419311.99	6101526.23	2	4	5	1218	2894	2433	15982	17407	2667	1	0
No Name 68	11N	409850.74	6106181	2	4	4	70	2037	4254	7748	14077	162	1	0
No Name 69	11N	409545.18	6106919.28	2	2	6	672	2635	3510	7194	13550	1094	1	0
No Name 70	11N	408481.02	6105552.65	2	4	35	1270	3570	4885	5673	15120	1247	1	0
No Name 73	11N	404552.13	6102851.08	2	5	34	440	402	2943	694	14275	521	1	0
No Name 74	11N	397641.59	6101725.06	2	2	13	546	1215	609	507	7699	636	1	0
No Name 86	11N	457810.18	6064567.22	2	4	2	510	580	572	44158	9471	290	1	0
No Name 87	11N	455497.61	6064489.11	2	4	34	232	252	206	41583	11383	255	1	0
No Name 88	11N	450908.54	6064787.35	2	4		1995	2902	3002	38111	15670	3843	1	0
No Name 89	11N	447749.1	6070503.66	2	5		1996	5422	3180	37199	14056	3848	1	0
No Name 93	11N	445073.43	6084508.79	2	3	6	2174	4436	627	40464	180	195	1	0
No Name 97	11N	472369.69	6114507.39	2	4	3	480	2855	581	70098	11457	303	0	1
Pelican Lake	11N	457300	6098100	2	3	95	1310	2650	233	53272	5338	206	1	0
Ponita Lake - North	11N	320400	6156900	2	2	29	177	767	225	7628	30167	184	1	0
Porter pond	11N	407773	6113489	2	3	13	308	952	273	11258	7605	982	0	1
Pouce Coupe River 3 (SE Cutbank)	11N	333900	6174000	2	6	20	438	510	820	29473	15317	338	1	0
Preston Lake	11N	315000	6140000	2	4	257	0	0	261	4614	20005	250	1	0
Ray Lake	11N	317800	6146700	2	3	133	660	907	22	5	22573	921	0	1
Simonette River 10 (Side Lake) North	11N	441200	6079500	2	5	160	452	649	4034	34265	3557	340	1	0
Simonette River 10 (Side Lake) South	11N	441200	6079500	2	1	160	452	649	4034	34265	3557	340	1	0

Name	Zone	Easting	Northing	Adult	Cygnets	Area (ha)	Well site	Oil	Road	Railway	Powerline	Pipeline	Green Zone	White Zone
Simonette River 2	11N	448000	6089400	2	2	8	1307	4289	1454	46128	4718	1810	0	1
Sinclair Lake (Brainard Lake)	11N	326000	6142000	2	3	360	194	232	21	4040	13718	244	0	1
Smoky River	11N	395900	6082900	2	5								1	0
Swan Lake 1	11N	451977.3	6099894.21	2	1	36	1010	1884	1720	48742	5383	454	0	1
Swan Lake 2	11N	450080.78	6100163.36	2	1	41	2372	3456	1923	46573	7369	859	0	1
Two Lakes - North	11N	454500	6129500	2	6	49	11	3320	4	52936	16570	1560	1	0
Valhalla Lake	11N	344750	6139550	2	5	110	253	747	16	7834	2692	238	0	1
Valhalla P.O.	11N	346450	6146850	2	3	30	79	48	91	14714	10779	0	0	1
Wabatanisk Creek 3	11N	459900	6128600	2	4	20	2163	7682	5204	54547	20627	3490	1	0
West Goose	11N	460869.44	6091481.36	2	4	40	486	593	771	57466	4091	706	1	0
West Goose - N	11N	460421.83	6092634.47	2	5		486	593	771	57466	4091	706	1	0
Whitham Lake	11N	328200	6144300	2	2	205	393	623	268	7502	15110	284	0	1
Wolfe Lake	11N	361450	6144800	2	5	103	435	313	149	24897	5029	301	0	1
Wood Lake	11N	390100	6113200	2	6	98	70	3539	43	2248	0	1136	0	1
Yoke Lake	11N	330250	6122100	2	4	60	214	513	85	11476	1822	110	0	1

Appendix D: Trumpeter Swan survey data collected from the 2010 Trumpeter Swan Continental Breeding survey provided by Alberta Sustainable Resource and Development Fish and Wildlife department. This data was used for the analysis of swan productivity in relation to human disturbance.

Name	Zone	Easting	Northing	Adult	Cygnets	Area (ha)	Well site	Oil	Road	Railway	Powerline	Pipeline	Green Zone	White Zone
Albright Lake	11N	322000	6152700	4	2	308	338	1169	56	5071	25024	452	1	0
Allingham	11N	320705	6120149	2	6	12	731	1755	119	16652	10833	807	0	1
Anderson Lake	11N	357650	6134600	4	7	138	409	359	55	17215	355	149	0	1
Bald Mountain	11N	369800	6081200	2	6	21	233	428	379	22738	14931	321	1	0
Barr Creek 2	11N	318500	6121150	2	4	27	407	1583	313	15545	12959	480	0	1
Bezanson S	11N	411116	6118248	2	4	21	63	3110	29	16960	1936	447	0	0
Boone Creek Southwest	11N	336250	6157550	2	3	34	570	1157	325	20219	23291	291	1	0
Boone Creek SW	11N	336250	6157550	2	3	34	570	1157	325	20219	23291	291	1	0
Boone Lake - East	11N	350600	6162450	2	3	86	403	125	446	30200	15133	335	1	0
Boone Lake - West (Jackfish Lake)	11N	336200	6162000	2	1	256	429	465	365	22512	16873	584	1	0
Bowman Lake	11N	350200	6107150	1	1	20	343	1066	353	7738	5342	52	0	1
Buffalo Lake	11N	375000	6138500	2	5	148	392	591	0	10275	3343	3	0	1
Calahoo Creek 3	11N	313550	6079900	4	2	153	620	3400	671	49839	28367	436	1	0
Cattail Lake - East	11N	458350	6134200	2	5	13	721	10101	74	48938	23896	1298	1	0
Chain Lake - Northeast	11N	315850	6144450	2	5	15	494	504	507	4078	23547	194	1	0
Dickson Lake	11N	319050	6155650	2	5	38	278	1669	51	5858	29722	575	1	0
Dickson Lake - Northwest	11N	317750	6158200	2	5	10	561	706	715	7131	32622	492	1	0
Dimsdale Lake	11N	372400	6113600	2	3	71	877	829	142	212	816	691	0	1
Driftwood Marsh (Ducks Unlimited)	11N	323700	6124750	2	6	70	388	686	119	10678	8809	469	0	1
Dune's project #1	11N	406940	6113558	2	5	140	532	470	68	10210	7650	454	0	1
Economy Creek 10 (Tyke Lake)	11N	419600	6090700	2	2	51	715	3451	42	19069	7343	767	1	0
Economy Creek 2a	11N	420600	6086300	2	5	10	1193	8281	469	22539	3238	3613	1	0
Economy Creek 4	11N	427100	6085450	4	9	86	2030	12420	4823	28252	2021	2526	1	0
Economy Creek 6 (East Dietz Lake)	11N	429750	6086400	2	5	130	1298	10145	7133	29529	3030	3069	1	0
Ellenwood Lake	11N	417100	6096350	3	2	105	699	1000	1785	14145	12392	314	1	0
Elmworth East	11N	335266	6102417	2	4	22	500	639	27	19404	2878	128	0	1
Fallow Lake	11N	456900	6125800	6	3	66	1650	6858	3991	56953	16336	6631	1	0

Name	Zone	Easting	Northing	Adult	Cygnets	Area (ha)	Well site	Oil	Road	Railway	Powerline	Pipeline	Green Zone	White Zone
Flyingshot Lake	11N	381500	6111800	2	2	158	444	1229	37	165	527	194	0	1
Flyingshot Lake - Northwest	11N	379800	6113150	2	7	169	34	881	0	128	630	48	0	1
Fowel Lake	11N	331100	6119450	2	5	29	225	1074	129	12270	452	578	0	1
Goodfare Lake	11N	329250	3128250	2	7	110	278	988	362	7047	4048	302	0	1
Goodfare Lake - West	11N	323500	6131650	2	6	38	531	924	534	4706	10390	236	0	1
Hermit Lake	11N	375000	6119000	2	3	220	594	721	24	5365	6122	243	0	1
Horse Lake	11N	328000	6135300	2	5		179	300	59	5	7297	153	0	1
Horse Lake	11N	328246	6137149	2	4		104	192	48	0	8358	0	0	1
Hume Creek - East	11N	315200	6130150	2	4	13	544	2488	584	9811	18280	571	0	1
Intermittent (Hudz)	11N	377400	6134650	3	6	104	229	1415	7	8183	545	101	0	1
Kamisak	11N	324970	6118534	2	4	203	351	2918	560	17908	6450	568	0	1
Kamisak Lake	11N	324950	6116200	2	6	203	351	2918	560	17908	6450	568	0	1
Kamisak Lake - East	11N	326150	6116400	2	5	50	574	2330	488	18135	5418	1755	0	1
Kamisak Lake 6	11N	321100	6114000	2	3	33	506	473	64	22008	9021	136	0	1
Kamisak Lake 6	11N	321045	6114065	2	3	33	506	473	64	22008	9021	136	0	1
Kamisak S	11N	324464	6113850	3	2	18	599	2629	582	21221	7024	541	0	1
Keeping Lake	11N	314450	6149800	2	4	26	793	658	573	51	27695	869	0	1
LaGlace Lake - West	11N	352850	6139400	2	6	13	340	1756	407	15812	3644	984	0	1
Latornell River 1	11N	432000	6072000	2	1	22	967	816	2481	23023	10730	718	1	0
Latornell River 2	11N	434700	6073800	2	5	15	1332	2775	2355	26023	9278	2294	1	0
Little Lake	11N	367150	6118750	2	6	132	247	1660	61	5247	6038	223	0	1
Little Puskwaskau Lake	11N	482400	6110100	2	5	163	912	2983	641	77004	921	501	0	1
Long Lake	11N	382000	6029800	5	4	163	679	927	474	21621	80	258	1	0
Long Lake - North	11N	464400	6085500	2	4	27	679	927	474	21621	80	258	1	0
McNaught Lake	11N	344000	6113550	2	6	274	331	3584	81	5143	66	185	0	1
McNaught Lake - South	11N	343625	6112400	2	5	32	327	3946	256	6305	273	833	0	1
McNeill Lake	11N	346650	6129150	2	5	19	347	220	225	4748	427	159	0	1
Mulligan Lake	11N	365500	6138100	2	5	306	110	0	138	20323	1009	3	0	1
No Name 100	11N	456611	6136422	2	2	65	2070	9935	2028	46676	24676	610	1	0
No Name 1004	11N	449774	6154647	2	5	7	2803	6512	1722	27874	37453	6076	1	0
No Name 119	11N	468883	6158303	2	1	8	387	1102	1609	28197	24999	942	1	0
No Name 148	11N	440723	6060072	2	4	1	2516	7743	3140	26669	22388	12029	1	0
No Name 179	11N	400925	6072195	2	6		1560	2136	1503	1788	8983	2096	1	0

Name	Zone	Easting	Northing	Adult	Cygnets	Area (ha)	Well site	Oil	Road	Railway	Powerline	Pipeline	Green Zone	White Zone
No Name 204	11N	350394	6201819	2	3		242	1270	623	38379	21839	920	1	0
No Name 22	11N	331472	6121452	2	3	7	486	610	496	10931	249	100	0	1
No Name 253	11N	329312	6182326	2	6	9	312	426	390	33671	19677	400	1	0
No Name 256	11N	337222	6184523	2	2	4	189	615	58	39395	12686	8	1	0
No Name 297	11N	339276	6173035	2	3	17	444	477	627	32747	10703	682	1	0
No Name 303	11N	319924	6166227	2	4	3	389	2325	9	14992	31152	292	1	0
No Name 325	11N	308432	6077801	2	4	4							1	0
No Name 361	11N	410808	6106847	2	3		755	598	4016	9127	13257	119	1	0
No Name 362	11N	424865	6095364	2	5	7	3785	4394	3808	22680	12436	4771	1	0
No Name 369	11N	414992	6108197	2	3	2	1299	3085	5216	13106	11211	2781	1	0
No Name 376	11N	407541	6104048	2	5		3061	4103	6215	4538	16754	1398	1	0
No Name 389	11N	418351	6103032	2	1	4	3277	4954	3304	15135	15758	3846	1	0
No Name 421	11N	381193	6107784	2	6	1	1396	2886	58	4429	822	957	0	1
No Name 446	11N	312750	6144296	2	1	23	79	1785	203	4723	25470	365	1	0
No Name 499	11N	410019	6086560	2	4	9	2093	4531	3861	13546	2379	1519	1	0
No Name 500	11N	416945	6081973	2	2	1	1977	10055	2097	20188	1024	1757	1	0
No Name 503	11N	413687	6073431	2	3		873	1058	834	10879	9830	836	1	0
No Name 505	11N	423045	6076376	2	2		1098	4329	1155	19073	6417	1340	1	0
No Name 52	11N	426157	6087093	2	3		1523	11434	4411	27369	3959	4777	1	0
No Name 526	11N	414102	6086631	2	1		2373	8463	5281	17221	3238	466	1	0
No Name 547	11N	414159	6069148	2	2	4	2747	2936	2864	7548	13778	1899	1	0
No Name 566	11N	424596	6094647	2	5	6	4623	4886	4633	22485	11513	5119	1	0
No Name 568	11N	455446	6087431	2	1		999	1246	501	51234	2575	585	0	1
No Name 569	11N	445499	6081284	2	6		229	152	0	12217	0	0	1	0
No Name 571	11N	464994	6092474	2	4		2998	3319	3814	60150	4230	2173	1	0
No Name 576	11N	466417	6074743	2	2	361	536	591	388	55800	10234	184	1	0
No Name 577	11N	462087	6090916	2	1	246							1	0
No Name 59	11N	420178	6103905	4	2		3921	5455	1967	16745	14637	5270	1	0
No Name 597	11N	448883	6071943	2	2	3	1471	6634	4969	38844	12789	2036	1	0
No Name 62	11N	418645	6099231	2	3	3	909	2818	2204	14961	16170	2058	1	0
No Name 635	11N	443788	6141976	2	6	14	2896	8763	2686	39605	23953	45	1	0
No Name 637	11N	453646	6139325	2	6	4	2196	8754	5472	43469	25160	734	1	0
No Name 648	11N	462353	6143253	2	4	2	3213	4002	1980	40998	27034	1742	1	0

Name	Zone	Easting	Northing	Adult	Cygnets	Area (ha)	Well site	Oil	Road	Railway	Powerline	Pipeline	Green Zone	White Zone
No Name 66	11N	412911	6106096	2	3	2	350	989	5307	10010	13755	127	1	0
No Name 670	11N	459039	6129724	2	3	6	1553	8452	4325	53842	20861	4008	1	0
No Name 677	11N	460711	6124374	2	3	17	682	7323	4793	59273	17979	3566	1	0
No Name 714	11N	309651	6115790	2	2	8	409	405	342	24723	21691	357	1	0
No Name 717	11N	316611	6114989	2	2	10	478	385	660	22535	14685	465	0	1
No Name 726	11N	311376	6100793	2	1	36	759	2800	157	37941	20402	196	1	0
No Name 730	11N	316426	6101686	2	4	2	640	1627	56	34299	15142	784	0	1
No Name 736	11N	344677	6168006	2	2	15	84	156	28	33407	11090	0	1	0
No Name 738	11N	345360	6173200	2	4	5	535	657	932	37019	6206	598	1	0
No Name 743	11N	383575	6145664	2	3	5	1095	615	147	6893	11063	1047	0	1
No Name 745	11N	400386	6133180	3	4	2	92	1141	51	11250	6152	531	0	1
No Name 753	11N	399486	6149265	2	3	839	1341	2610	1458	4086	3997	2447	1	0
No Name 80	11N	461466	6044838	2	2	2	609	3248	718	45386	2331	3800	1	0
No Name 81	11N	460784	6039138	2	4	12	1002	4415	1035	42520	1634	2506	1	0
No Name 819	11N	454673	6096263	2	4		1154	1303	771	51795	8540	2	1	0
No Name 830	11N	466443	6098485	2	4		1305	1513	732	63255	2347	1479	0	1

Appendix E: The swan counts for the given survey blocks for the 2000, 2005, and 2010 surveys. The blank boxes for the 2010 surveys are blocks that were not surveyed.

Mapsheet	2000	2005	2010
083B13	0	0	
083B15	0	0	
083B16	0	0	
083C16	0	0	
083E16	0	0	
083F01	0	0	
083F03	0	0	
083F04	0	0	
083F05	0	0	
083F06	2	0	
083F07	0	0	
083F08	0	0	
083F09	0	2	
083F10	5	10	8
083F11	0	2	
083F13	0	0	
083F14	0	0	
083F15	0	0	
083F16	3	3	
083G01	0	0	
083G02	2	9	
083G03	0	0	6
083G04	0	0	
083G05	3	2	4
083G06	3	5	6
083G07	0	0	
083G08	0	0	
083G10	0	0	
083G11	4	2	
083G12	0	1	
083G13	0	0	
083G14	0	0	
083J02	0	0	7
083J03	0	0	5
083J04	3	18	5

Mapsheet	2000	2005	2010
083J05	0	0	2
083J06	0	7	17
083J07	0	0	
083J10	0	0	
083J11	0	0	
083J12	0	0	
083K01	0	4	
083K02	0	0	11
083K03	0	0	7
083K04	0	1	5
083K05	0	2	
083K06	0	7	5
083K07	0	0	14
083K08	0	0	
083K10	0	2	24
083K11	1	2	13
083K12	7	27	30
083K13	7	85	164
083K14	6	5	
083K15	0	0	
083L01	0	0	
083L08	0	0	
083L09	0	2	
083L10	2	2	
083L11	0	0	
083L12	2	4	
083L13	5	10	41
083L14	3	4	44
083L15	5	12	25
083L16	2	87	137
083M01	0	79	83
083M02	3	44	98
083M03	3	22	39
083M04	3	103	202
083M05	0	72	114
083M06	0	193	315
083M07	0	56	52
083M08	0	0	

Mapsheet	2000	2005	2010
083M09	0	0	
083M10	0	6	
083M11	2	14	17
083M12	2	45	67
083M13	2	4	16
083M14	2	9	13
083M15	0	0	0
083M16	0	0	
083N02	0	0	
083N03	6	10	31
083N04	6	22	76
083N05	0	67	133
083N06	0	0	
083N07	0	0	
083N08	0	0	
083N09	0	2	
083N10	0	0	
083N11	0	0	
083N12	0	10	27
083N13	0	5	1
083N14	0	0	
083N15	7	19	
083N16	0	0	34
083O09	0	0	
083O10	0	0	
083O11	0	0	
083O12	0	0	
083O13	0	2	47
083O14	0	0	
083O15	0	4	18
083O16	0	2	4
084B01	0	0	
084B02	0	4	13
084B03	26	5	10
084B04	16	56	150
084B05	16	10	16
084B06	0	0	
084B07	10	5	17

Mapsheet	2000	2005	2010
084B08	0	10	11
084B10	1	4	
084B11	0	0	
084B12	6	6	13
084B13	2	7	
084B14	0	0	
084C01	0	9	
084C02	3	0	
084C07	8	0	
084C08	0	0	
084C09	32	5	
084C10	8	0	60
084C15	0	0	26
084C16	11	0	37
084F01	0	0	
084F02	0	0	
084F07	0	0	
084F08	0	0	
084G03	0	0	
084G04	3	3	
084G05	0	0	