University of Alberta

Patterns of raptor electrocution mortality on distribution power lines in southeast Alberta

by

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ABSTRACT

Avian mortality associated with power lines has been a persistent problem since power line development. I studied raptor electrocutions on distribution (< 69kV) lines in southeast Alberta, Canada from 2003 – 2004. I examined species, sex, and age most affected, mortality rates of pole configurations, scavenging pressure, and species' pole use. Over six weeks, six confirmed and 14 unconfirmed electrocutions were documented beneath 379 poles during field surveys. When all evidence was considered, three-phase transformers and single-phase double deadends were responsible for significantly more mortality than other structures. Utility reports documented 35 great horned owl and 18 red-tailed hawk electrocutions; most were adults and females. Three-phase transformers and riser structures were most lethal. Scavengers removed almost half of experimental carcasses within seven days. Based on this information, I estimate total loss to electrocution within the 13 400km^2 study area to be 542 - 2762 raptors over a 6-week period in summer.

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LIST OF ABBREVIATIONS

a.s.l.:	above sea level
DDT:	dichlorodiphenyltrichloroethane
DDE:	1,1-dichloro-2, 2-bis (p-chloroplienyl) ethylene
GHOW:	great horned owl
KV:	kilovolts
LMBs:	large mammal burrows
MBCA:	Migratory Birds Convention Act
MBTA:	Migratory Bird Treaty Act
P:	pellets
PH:	phase
PR:	prey remains
RTHA:	red-tailed hawk
SWHA:	Swainson's hawk
WW:	whitewash

Pole Categories

1CR:	single-phase corner
1DD:	single-phase double deadend
1DE:	single-phase deadend
1FU:	single-phase cutout
1RB:	single-phase regulator bank
1RC:	single-phase recloser
1TG:	single-phase tangent
1XR:	single-phase transformer

3CB:	three-phase capacitor bank
3CR:	three-phase corner
3DD:	three-phase double deadend
3DE:	three-phase deadend
3DEM:	three-phase modified deadend
3FU:	three-phase cutout
3GA:	three-phase gang switch
3RC:	three-phase recloser
3TG:	three-phase tangent
3UG:	three-phase overhead to underground riser
3XR:	three-phase transformer
SP:	service pole

Chapter 1: Introduction

1.1. Raptors in the Ecosystem

Raptor, (or bird of prey), is the collective term for hawks, eagles, falcons, kites, vultures and owls. During medieval times and for centuries before, raptors, particularly falconry birds, were held in high regard. However, in later centuries and well into the 1900s, these birds were increasingly considered vermin, particularly those known for the depredation of game species and domestic farm animals. Their direct persecution was encouraged by the United States government as late as the 1940's (Nelson and Nelson 1976), and in many provinces in Canada until the 1950's (Gordon Court 2005, personal communication). However, the general attitude towards these predators has changed over the past several decades. Thanks to the work of many biologists and conservationists, the largely unfounded prejudice towards raptors has been replaced by sound science that has highlighted the value of these birds in ecosystems both as predators and as indicators of ecosystem health.

Most species of raptors occupy the highest trophic level within food webs and thus often play an integral role in maintaining the balance and viability of lower trophic levels. Humans have come to realize the importance of raptors in the ecosystem, for instance in agricultural systems, where rodent control by raptors limits damage to crops as well as the spread of disease (Bosakowski and Smith 2002).

Because birds of prey are highly visible and often well studied, they are frequently the first to signal environmental problems caused by habitat degradation or pollutants. At the top of the food chain, they are vulnerable to bioaccumulation of heavy metals, pesticides, or other pollutants. An excellent illustration of this phenomenon was the devastating effect of DDT (dichlorodiphenyltrichloroethane) on raptors following widespread application of this pesticide after the Second World War. Scientists soon observed a dramatic decline in populations of many raptors, particularly the peregrine falcon (*Falco* *peregrinus*). Upon further investigation, they discovered a direct connection between population declines and DDT use. Specifically, DDE [1,1-dichloro-2, 2-bis (p-chloroplienyl) ethylene], a metabolite of DDT, accumulated in the fatty tissues of prey species, and consequently falcons were exposed to the pesticide through consumption of these animals. Elevated levels of DDE in the tissues of adult falcons resulted in a thinning of their eggshells, reproductive failure, and overall low levels of reproductive success. DDT was banned in the United States and Canada in the 1970's, and many populations of peregrine falcons and other raptors have since seen a substantial recovery (Johnstone et al. 1996).

1.2. Benefits of Power Lines

Power lines benefit raptors in many ways. The introduction of utility poles into prairie regions opened up a large area that was once unable to support as many raptors because of a lack of available trees from which to hunt. Power poles not only provide hunting perches, but they also provide structures on which raptors nest, roost, and eat. In fact, literature from the mid-1980's even promotes using utility structures as a passive tool for raptor conservation (Reinert 1984).

1.3. History of Raptor Electrocution

In addition to natural mortality sources such as disease and competition with conspecifics, raptors have for many years experienced human-caused mortality that has accompanied industrialization. Such mortality includes collisions with vehicles, direct or indirect poisoning, loss of habitat for themselves or that of their prey, direct persecution, and mortality associated with power lines. The latter encompasses collisions with wires, entanglement with insulators, and electrocution.

Electrocution occurs when a bird becomes a current-carrying portion of the circuit by spanning the distance between two energized components (or "phases"), resulting in a phase-to-phase electrocution, or when it simultaneously contacts one energized component and one grounded component, leading to a phase-to-ground contact. Under normal, dry conditions, contact is generally made between two fleshy parts of the body including, but not limited to, wrists, feet, or the beak. Under wet conditions, feathers may make this contact. Electrocution typically occurs on lines less than 69kV (69 000v), known as distribution lines; transmission lines, or those greater than 69kV, rarely electrocute raptors due to the increased clearances between energized components (Boeker and Nickerson 1975). Unless otherwise indicated, "power lines" herein refer solely to distribution lines.

The first record of avian mortality from power lines dates back to the late 1800's (Coues 1876), and at least one record of electrocution was made as early as 1922 (Hallinan 1922). However, this source of mortality for birds of prey was not fully realized until the early 1970's, when an investigation into the causes of death for eagles in Wyoming and Colorado led to the discovery of many carcasses beneath power lines (Olendorff et al. 1981). Since then, many partnerships have been established between utility companies, government agencies, conservation organizations, and academic institutions in order to discover ways to mitigate this problem.

Research on the issue is by no means limited to the United States. Studies examining raptor electrocution have been conducted in countries including, but not limited to, Canada (Holland and Curtis 1997), Mexico (Manzano-Fischer 2004), Italy (Sergio et. al 2004), Spain (Ferrer et al. 1991; Janss 2000; Janss and Ferrer 2001), South Africa (Kruger 2000), and Norway (Bevanger 1994). Since this problem has the potential to occur wherever power lines and raptors co-exist, it is only expected to intensify as less-developed countries industrialize (Bevanger 1994).

1.4. Factors Influencing Electrocution

There is no single factor that determines whether an electrocution event will occur. Numerous contributing factors exist that are not mutually exclusive; they can operate individually or collectively, and this leads to high variability in frequency of occurrence of electrocutions both at local and landscape level scales. They can be broadly classified into environmental, technical and biological factors. Environmental factors include local climatic conditions such as precipitation and wind, as well as habitat characteristics including land use practices and prey availability. Technical factors are those related to the engineering side of the issue, such as power pole configurations and construction materials. Biological factors include species, age, sex, and behavior, especially with respect to seasonal activities. Technical factors will be discussed in detail in Chapter 2, while biological and environmental factors will be explored in depth in Chapter 3.

1.5. Sensitive Species

Mortality stemming from power lines can have significant negative effects on populations of rare or endangered species. Moreover, these effects are often additive to the primary cause of population decline. For example, the Spanish imperial eagle (*Aquila adalberti*), one of the world's most endangered raptors, experiences a loss of an estimated 1.3% of the adult population and 30% of the juvenile population to electrocution on an annual basis (Janss and Ferrer 2001). In fact, within Doñana National Park, 69% of Spanish imperial eagle deaths were the result of electrocution (Ferrer et al. 1991). Electrocution has been identified as a threat to the endemic and threatened Cape Griffon vulture (*Gyps coprotheres*) in South Africa (Kruger 2000), as well as the endangered Egyptian vulture (*Neophron percnopterus*) in the western Palearctic (Nikolaus 1984; Donazar et al. 2002). In North America, electrocution has proven to be a considerable challenge to the reintroduction program of the endangered California condor (*Gymnogyps californianus)* (Snyder and Snyder 2000; Sorenson et al. 2000). In some cases this source of mortality is the leading cause of death for a species: after reviewing multiple published studies, Sergio et al. (2004) discovered that electrocution was cited as the primary cause of mortality of the eagle owl (*Bubo bubo*), a species of vulnerable conservation status, in 68% of the studies. Furthermore, electrocution has increased for this species over the past 30 years (Sergio et al. 2004). Electrocution was also documented as the primary cause of mortality for bald eagles (*Haliaeetus leucocephalus*) in one study in western Canada (Wayland et. al. 2003).

Under the provincial Wildlife Act, the ferruginous hawk (*Buteo regalis)* and peregrine falcon are listed as legally Threatened Species, and the prairie falcon *(Falco mexicanus)* is listed as a Species of Special Concern (Alberta Sustainable Resource Development 2003). Van Horne (1993) noted that ferruginous hawks frequently use power poles when hunting, and that they utilize oilfields (which have a high density of transformer structures that service oil wells) significantly more than expected, based on their observed use compared to that of Swainson's hawks (*Buteo swainsoni*), red-tailed hawks (*Buteo jamaicensis*), and northern harriers (*Circus cyaneus*). Indeed, interaction with and subsequent mortality from power lines has been well documented for the ferruginous hawk, peregrine falcon and prairie falcon in other parts of the world (Benson 1981; Harness 1997; Kruger 2000; Liguori 2003).

1.6. Legislation Regarding Raptors

The Migratory Birds Convention, which was signed between the United States and Canada in 1916, enabled both countries to enact legislation to protect most species of birds that migrated between the two countries (U.S. Fish and Wildlife Service 2002). This led to the Migratory Birds Convention Act (MBCA) of 1917 in Canada (Environment Canada 2002) and its counterpart, the Migratory Bird Treaty Act (MBTA) of 1918 in the U.S. (U.S. Fish and Wildlife Service 2002). Despite the fact that raptors are currently afforded protection under the MBTA, there exists no such protection for raptors under the MBCA because these birds were still considered pests at its inception. Nevertheless, attitudes have changed, and raptors have since been granted protection under provincial and territorial legislation. In Alberta, this protection is under the Wildlife Act of 1984 (Alberta Sustainable Resource Development 2002).

The Alberta Wildlife Act has penalties for destruction of raptors similar to those of the MTBA in the United States. A corporation could face a fine up to $100 000 and individual imprisonment up to two years for a violation of the act (Alberta Sustainable Resource Development 2005). Although raptors are afforded this legal protection, only rarely would such an extreme measure be necessary, but such a scenario has occurred in the United States. In an unprecedented case, the Moon Lake Electrical Association (MLEA), was charged in 1999 under the MBTA and the Bald and Golden Eagle Protection Act for electrocuting numerous eagles, hawks, and an owl on their lines over a three-year period. The company had been repeatedly warned to retrofit dangerous structures but failed to sufficiently act; in addition to having to retrofit all dangerous structures and hire a consultant to oversee an avian protection plan, they were ordered to pay $50 000 in fines and $50 000 to a raptor conservation organization (Melcher and Suazo 1999).

Nonetheless, charges against utilities are seldom necessary; most companies recognize the problem and have programs in place to deal with raptor electrocutions. These programs can fall anywhere on the spectrum from minimal reactive measures such as retrofitting poles that have already killed birds, to proactively retrofitting potentially dangerous poles while incorporating raptor protection into new designs, commissioning research to determine specific details of the problem, and instituting ongoing monitoring programs to assess the effectiveness of these measures.

1.7. Issues Beyond Conservation

Issues associated with electrocution go far beyond that of raptor conservation. In a survey of 560 American utilities, “wildlife” was cited as the third leading identifiable cause of power outages, and birds comprised the largest proportion of those outages (Southern

Engineering Company 1996). Within its service area in Alberta, ATCO Electric conservatively estimates that 12% of annual outages are the result of avian activity; however, birds are also likely responsible for many of the outages categorized as “unknown”, which represent an additional 15% of outages each year (Brian Harris 2004, personal communication). Estimates of the cost to the power industry for bird-related outages were unavailable for Alberta, however in the neighboring province of British Columbia, the 2500-3000 annual wildlife-related outages cost utilities approximately $2 million for repairs each year (Canadian Electricity Association 2004). In California, annual economic losses of almost $1 billion ensue from avian-related power outages (Hunting 2002). Such power loss can lead to substantial lost revenue not only to the utility itself, but also for the commercial industries that it serves.

Costs of avian interaction with power lines are by no means limited to economic costs. Compromised system reliability leads to customer dissatisfaction, and public awareness of power lines causing avian mortality can lead to negative publicity. It can also have impacts beyond the realm of power interruptions. In July of 2004, a 6 000 acre grassfire caused by the carcass of an electrocuted red-tailed hawk forced the evacuation of 1600 homes in San Clarita, California (CNN 2004).

1.8. Justification and Research Objectives

The impact of electrocution on raptors in Alberta is unknown. Results from elsewhere in North America or globally cannot necessarily be extrapolated to Alberta for a number of reasons. First, from a biological perspective, geographical variation occurs with respect to species composition, population densities and activities each species undertake (breeding, migration, overwintering, etc). Secondly, landscape variables such as topography, vegetation, presence of water bodies, and extent of human development can vary among regions. Third, the proportion and characteristics of power poles employed varies within and among utilities around the world due to differing consumer needs and electricity demand, materials available for construction, and national construction standards.

Finally, local climatic factors such as the amount of precipitation, seasonal temperature extremes, and wind speed and direction can substantially vary. All of these factors influence the rate of electrocution mortality that each region may experience.

Despite the plethora of research that has surfaced since the early 1970's, mortality rate estimates for various pole designs are largely unavailable in the literature, and many studies are inherently biased in data collection (Lehman 2004). Additionally, a need exists for a study that compares the estimated mortality rate with that reported by utility companies (Harness 1997). This study aims to address some of these shortcomings existing in the literature for Alberta.

The objectives of this research project were to (1) identify the structures that pose the largest electrocution threat to raptors within ATCO Electric's distribution system, (2) determine which species, age and sex of raptors are most affected by this form of mortality, (3) describe the discrepancy between the actual number of raptors lost to electrocution and losses reported by the utility, (4) describe how raptors in the study area utilize power poles, and (5) obtain an estimate of mortality spanning the entire study area.

1.9. Thesis Overview

I studied raptor electrocution on distribution power lines in southeastern Alberta over the period of April 2003 – December 2004. Chapter 2 describes fieldwork conducted during the summer of 2003 to address objectives (1) and (5) above. I analyze evidence of electrocution beneath various configurations of power poles and obtain an estimate of total mortality spanning the entire study area. Chapter 3 examines electrocution mortality as reported by the utility between April 2003 and December 2004, and it addresses objectives (1) and (2). Chapter 4 is based on supplementary data collected during the fieldwork and provides insight into objective (4). The final chapter ties findings from previous chapters together and in so doing, addresses objective (3). It concludes with a discussion of these findings in a management context for ATCO Electric's distribution system.

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Chapter 2: Patterns of electrocution across power pole configurations as discovered during electrocution evidence surveys

2.1. Introduction

Raptors use power poles for a variety of purposes including hunting, resting, feeding, nesting, and establishing territorial boundaries (APLIC 1996). The combination of their frequent use and inadequate spacing of energized components creates an opportunity for electrocution to occur. As mentioned in Chapter 1, the configuration of a power pole and its associated construction materials are two factors influencing probability of electrocution, and can be classified as technical factors. These are discussed in more detail here.

Configurations of power structures are extremely variable and are influenced by line voltage, type of consumer use, electricity demand, construction materials available, and national or company construction standards. Numerous studies have identified the types of structures that are most lethal to raptors in various parts of the world. Regardless of single-phase or three-phase configuration, power structures that are often responsible for a disproportionately high number of electrocutions include those with transformers, jumper wires, and other protective equipment (Olendorff et al. 1981; O'Neil 1988; Bevanger 1994; Harness 1997; Olson 2000; Liguori 2003;); deadends (structures at the end of a line) (Harness 1997; Harness 2000b); and structures with ground wires leading to the top of the pole (Boeker and Nickerson 1975; Olendorff et al. 1981). Because of the large amount of hardware and connecting wires that these configurations support, they generally lack adequate clearance space necessary to prevent electrocution. Conversely, tangent structures, which lack any pole-mounted equipment, are usually responsible for a disproportionately small share of mortality (Harness 1997; Harness 2000b) and are generally considered safe for all but the largest of raptors. Finally, customer service poles (herein, “service poles”), which carry electricity from transformers to homes and businesses at low voltages (< 1000v), are generally not discussed in the literature but are somewhat similar in structure to single-phase deadend poles.

In North America, most crossarms and the poles on which they rest are made of wood, which is non-conductive when dry. More conductive materials such as steel or concrete (which is reinforced with rebar (Harness 2000a)), are more commonly used in Europe and can be more dangerous, especially for small and medium-sized birds (Janss and Ferrer 1999; Janss 2000).

2.1.1. Outages and Reporting Systems

Raptor electrocutions often result in a loss of power. When this occurs, utility service crews typically visit the site to locate the blown fuse, repair the damage, and investigate the cause of the outage (or fault). This is usually accomplished by patrolling the line in a vehicle. Protocol varies widely among utilities regarding the amount of detail collected on the incident; at a minimum, the fact that a bird caused a service interruption is usually reported.

Despite this reporting system, electrocution mortality may go underreported for three reasons: first, during a temporary fault, many distribution lines automatically deploy a system called “three shot reclosing”, where the line will attempt to re-energize itself three times (Robert Rose 2005, personal communication). If successful, it eliminates the need for service crews to manually reset the line, thus the site is not investigated for the cause of the fault. Second, some carcasses may simply go unnoticed during power outage investigations. Service crews patrolling the line by vehicle may miss carcasses obscured by vegetation or they may concentrate more search effort around what they consider to be more lethal poles, inadvertently missing carcasses beneath structures considered less dangerous. Finally, and arguably most importantly, not all electrocutions result in a power outage (APLIC 1996; Harness and Wilson 1998). In fact, research by Dwyer (2004) indicated that more than 90% of Harris’ hawk (*Parabuteo unicinctus*) electrocutions were not associated with power outages. Because of this potential for under-reporting, utility records alone may not provide a reliable estimate of true mortality. Field surveys are a critical component of research projects that aim to obtain an accurate picture of electrocution mortality on the landscape.

Estimates of the true severity of electrocution vary widely in the literature. Difficulty in comparison among regions and years is compounded by the lack of a standardized method of comparing results; study designs and objectives are as variable as the regions from which the results originate. Despite this, results from other studies provide some indication of the size of the problem. In a study spanning six western states, 400 raptor carcasses were found along a total of approximately 192 km of line over 22 months of sampling between 1977 and 1979 (Benson 1981). Ferrer et al. (1991) estimated an annual loss of 1200 raptors to electrocution on the 300 km of power structures in and around Doñana National Park in Spain. More recently, Dwyer (2004) confirmed 150 raptor deaths due to electrocution in a 1000 km^2 urban environment over a 20-month period. Clearly, electrocution is a substantial source of raptor mortality and may affect local populations.

2.1.2. Scavenging Pressure

The abovementioned estimates of mortality were obtained by systematically patrolling sections of power lines to count the number of carcasses discovered beneath structures. With any such investigation, a period inevitably exists between an electrocution occurring and the time at which an investigator discovers it. In that time there is potential for a scavenger to discover and remove the carcass (Olendorff et al. 1981), thereby reducing the estimate of mortality and potentially underestimating the impact of electrocution. Scavengers may even learn to routinely patrol lines in search of such power line victims (Bevanger et al. 1994). Therefore, when an attempt is being made to quantify mortality due to electrocution, one must account for this factor.

Within the southeastern portion of Alberta, many potential facultative scavengers exist, and are outlined in Table 2.1. The only obligate scavenger occurring in this area is the turkey vulture (*Cathartes aura*).

Table 2.1 Potential facultative scavengers in the study area

	Common Name	Scientific Name
Mammals	American badger	*Taxidea taxus*
	coyote	*Canis latrans*
	least weasel	*Mustela nivalis*
	long-tailed weasel	*Mustela frenata*
	red fox	*Vulpes vulpes*
	skunk	*Mephitis mephitis*
	domestic dog	*Canis familiaris*
	domestic cat	*Felis catus*
Raptorial birds	bald eagle	*Haliaeetus leucocephalus*
	golden eagle	*Aquila chrysaetos*
	broad-winged hawk	*Buteo platypterus*
	ferruginous hawk	*Buteo regalis*
	great horned owl	*Bubo virginianus*
	long-eared owl	*Asio otus*
	northern harrier	*Circus cyaneus*
	red-tailed hawk	*Buteo jamaicensis*
	rough-legged hawk	*Buteo lagopus*
	short-eared owl	*Asio flammeus*
	snowy owl	*Nyctea scandiaca*
	Swainson's hawk	*Buteo swainsoni*
Non-raptorial birds	American crow	*Corvus brachyrhynchos*
	black-billed magpie	*Pica pica*
	common raven	*Corvus corax*

This scavenging factor, commonly known as the removal bias, must be quantified to avoid underestimating total mortality. It is one of four potential biases outlined by Beaulaurier (1981) as factors that must be addressed when conducting dead bird searches beneath power lines. The others include detection bias, habitat bias, and crippling bias. Detection (or search) bias results from the inability of searchers to locate carcasses. It is influenced by terrain, target species, vegetation composition, and the experience of the investigator. Habitat bias occurs because portions of terrain are not searchable because of thick vegetation or presence of water bodies. Crippling bias results from birds falling outside of the predetermined search radius (Beaulaurier 1981).

This portion of the research project attempts to quantify the rate of raptor electrocutions beyond that which is reported by the utility. These would theoretically include carcasses that were either not discovered during outage investigations, or those events that did not cause a power outage. Records reported by the utility were analyzed separately in Chapter 3.

2.1.3. Research Objectives

The objectives for this component of the research were as follows: 1) determine the proportion of mortality at each structure type as it relates to its abundance on the landscape, 2) quantify the effect of scavenging pressure on the ability to recover electrocuted birds, 3) calculate the estimated rate of non-reported raptor electrocution per legal survey section (2.59 km^2) over 6 weeks in the breeding season, and 4) obtain the total estimate of non-reported raptor electrocution mortality across the study area after the loss to scavengers is taken into account.

I predicted that electrocution rates would be higher than expected on transformer structures, deadends, and poles with lightning arrestors, cutouts (or fuses) or jumper wires. I predicted electrocution rates to be lower than expected on tangent structures. I did not have a prediction on service poles before commencing the surveys. Detailed descriptions and photos of the abovementioned structures can be found in Table 2.2 and Appendix A, respectively.

2.2. Methods

2.2.1. Study Area

This study was conducted in the southeastern portion of the province of Alberta within ATCO Electric's service area (Figure 2.1). This region was one of two in the province identified by the utility as having an unusually high occurrence of avian-related system outages. Within the approximately 13 400km^2 study area, three sampling sites were established, one in each of the utility's service districts of Stettler, Forestburg, and Consort. The three sampling sites spanned as follows: 52˚07' to 52˚18'N latitude and 112˚07' to 112˚47'W longitude (Stettler), 52˚28' to 52˚29'N latitude and 111˚21' to 111˚34'W longitude (Forestburg), and 52˚06' to 52˚10'N latitude and 110˚26' to 110˚36'W longitude (Consort).

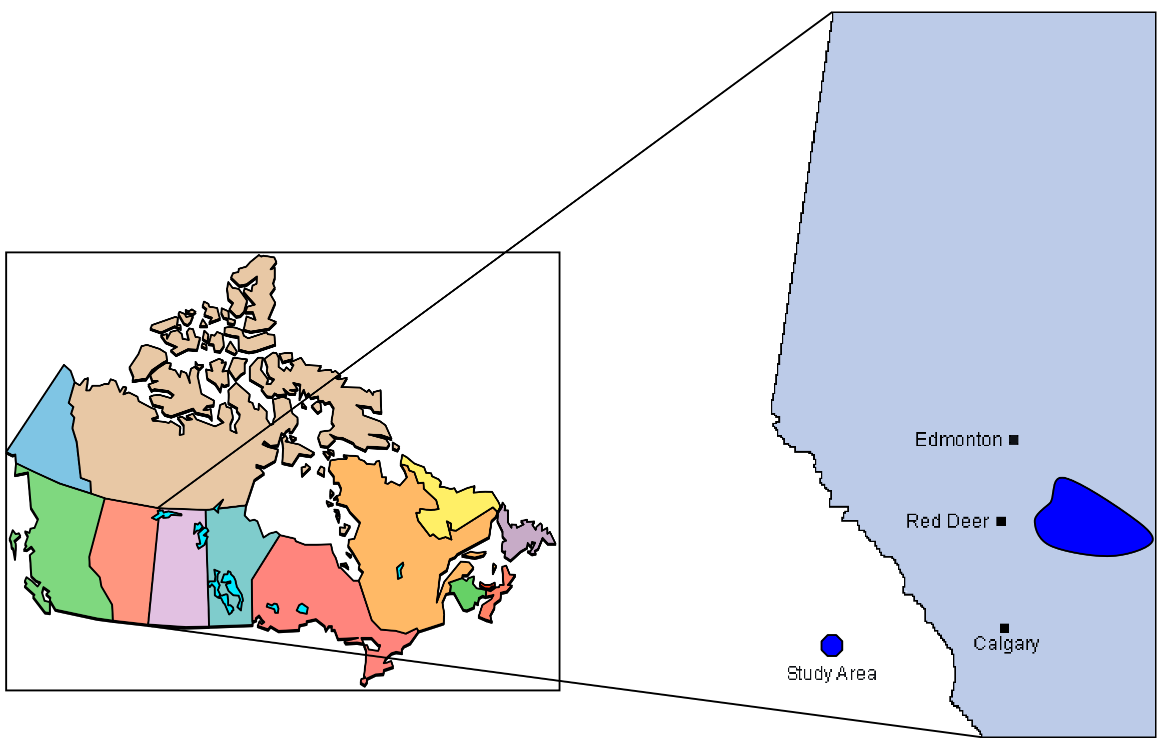

Figure 2.1. Study Area Map

Little variability exists within these three sites with respect to the composition of the landscape. They are situated within the Parkland region of the province, which is classified as a mosaic of aspen woodlands and prairie grassland (Moss 1994). Except for the occasional woodlot and a few uncultivated pastures, little of the natural vegetation exists today. Now considered oilfields, these three areas consist of a high density of oil and gas well sites and processing batteries surrounded by agricultural developments, including cereal crops and small livestock operations. The topography is of the larger study area is relatively flat with a few gently rolling hills and some small natural water bodies. Mean daily temperatures in the region range from -14ºC in January to +17.9ºC in July with an average annual precipitation of 429.4mm (Environment Canada 2002). Elevation fluctuates between 600-900m a.s.l. (Moss 1994).

Power lines investigated in this project were limited to single- and three-phase distribution lines. ATCO Electric (herein, the utility) is Alberta's major provincial electric power company, covering nearly two-thirds of the province and operating almost 68 000 km of distribution lines (ATCO Electric 2005). Single-phase lines operate at 7.2kV and 14.4kV, while three-phase lines operate at 24.9kV.

2.2.2. Site Selection

Western Canada employs the Range and Township Grid System, which essentially spatially divides the province into six-mile (9.66 km) wide "ranges" that run east to west, and six-mile (9.66 km) "township strips" that run south to north. Each range and township is assigned a sequential number beginning at the east and south borders of the province, respectively. This grid results in six-mile by six-mile squares called "townships". Townships are further divided into one-mile by one-mile (2.59km^2) "sections", which are the key unit of the township system. For the remainder of this document, the term "section" refers to the above definition.

Wildlife-related power outage reports for the three service areas for the years 2000-2002 were obtained from the utility. Unfortunately, the descriptive records were vague, with all wildlife-related outages classified as "bird/animal", as there was no previous requirement for reporting species involved. In the event that a utility serviceman voluntarily identified the species as a non-raptor, the record was eliminated. Outages were then tallied by sections to identify "hotspots" on the landscape.

2.2.3. Electrocution Evidence Surveys

This portion of the research was conducted June – August 2003. Prior to fieldwork, I broadly classified poles into two categories: "simple" or "complex". Simple poles referred to single- or three-phase tangent structures lacking additional hardware, which, when dry, are generally considered to be among the safer configurations for non-eagle birds of prey (Harness 1997). These structures simply carry electricity along the line and do not perform any other function. Complex poles included every other configuration of pole that had additional hardware such as lightning arrestors, transformers, cutouts, and jumper wires. Lightning arrestors and cutouts are pole-mounted devices that protect equipment from sudden surges of electricity, such as when lightning strikes the system or trees fall onto conductors. Transformers step down the voltage for private or commercial electricity use. Jumper wires make electrical connections between various pieces of equipment, such as transformers to the energized conductors or to connect a tap line to the main line.

As each pole in the study area was encountered, a random number table was consulted to determine if it should be sampled. However, simple structures are by far the most numerous on the landscape, and to minimize the sampling effort on "safe" structures, each simple pole had only a 10% likelihood of being sampled while each complex pole encountered had a 50% chance.

Each pole was surveyed twice, with an average of 43 days (approximately 6 weeks) between the first and second surveys. At each pole, data were collected on the placement of energized conductors, cutouts, lightning arrestors, jumper wires, ground wires and transformers. Information was also gathered on crossarm material, placement of guy wires, and whether the structure had any existing bird protection. The location (latitude/longitude) of the structure was recorded using a Garmin 12XL Global Positioning System unit. The 10m radius surrounding each pole was searched for evidence of electrocution (Janss 2000). During the second survey, grasses or crops at some poles had grown considerably since the first check, while some poles had the opposite effect, with vegetation much shorter than during the initial survey if grasses or crops had been recently cut or grazed. To counterbalance the effect of thicker vegetation on some poles, the radius was searched more intently, by walking slower and gently sweeping the vegetation to the side.

Any carcasses, bones, or feathers found were collected and labeled. The following information was recorded (if known): species, age, sex, nature of physical damage to carcass, location of evidence with respect to the pole, and any damage done to the structure. Evidence that could not be identified on site was frozen and later brought into a provincial government laboratory for further identification. An attempt was made to confirm the cause of death; presence of burnt feathers or burn marks elsewhere on the carcasses was presumed electrocuted. If remains of a raptor were found below a pole but cause of death could not be determined, electrocution could not be ruled out and the evidence was recorded as "unconfirmed". All remains found during the first check were removed to prevent double counting on the subsequent visit. It is important to reiterate that remains found beneath poles were those that were not detected by the power company. Service crews were collecting every carcass found during outage investigations as a separate component of this research (for more information, see Chapter 3).

2.2.4. Scavenger Assessment

This portion of the research was conducted simultaneously with the electrocution evidence surveys. In order to account for the rate at which scavengers could potentially remove raptor carcasses before I had the opportunity to discover it, a scavenging assessment was conducted. The carcasses of 50 freshly killed Single Comb White Leghorn chickens (*Gallus domesticus*) were obtained from the University of Alberta.

Each carcass was deposited within 1.5m of the base of 50 power poles in the Stettler sampling area. Poles were randomly chosen among those with suspected large mammal burrows within the 10m radius (n=21), and those without (n=29). Fewer poles with large mammal burrows were selected for the assessment than those lacking these burrows because of the relatively lower occurrence of the former in sampling areas.

The carcasses were assessed daily for seven consecutive days and weekly or every second week for six weeks thereafter to determine the extent to which the carcasses were scavenged. Carcasses were considered removed when less than 5% of the carcass was detectable within the 10m radius of the base of the pole. A 10m radius was chosen to be consistent with the area that would normally have been searched in an electrocution survey. The <5% of the carcass remaining was estimated as the point at which the carcass may not have been interpreted as being an electrocution victim during regular patrols, and is more conservative than the 10% suggested by Bevanger et. al. (1994).

2.2.5. Power Pole Inventory

In order to generate an estimate of raptor mortality that extends beyond the sampling sites to include the larger study area, the density of various configurations both within the oilfields as well as the surrounding rural lines was necessary. This information was not available from the utility so an inventory of all structures encountered during the electrocution evidence surveys, including any poles not sampled, was undertaken in October 2004.

The study area itself contains oilfields that exhibit a high density of power poles (herein "oilfield sections"), as well as non-oilfield, rural areas that contain a relatively lower density of poles (herein "rural sections"). During the selection of sections to sample in the electrocution evidence surveys, the 2000-2002 outage data primarily identified the oilfield areas as problematic with respect to avian interactions. Consequently, rural areas were not as heavily sampled during these surveys, resulting in fewer of these sections available for the inventory. To compensate for this, some additional randomly chosen rural sections were inventoried to augment that of the sampled areas.

Despite the fact that most utility companies utilize the same general designs of power poles, there is no universal classification system for categorizing them. Many modifications exist with respect to spatial separation of equipment and materials used in construction, depending on several factors including location of poles, customer need, population density, and climatic conditions of the region. For the purpose of this research project, I created a classification system of ATCO Electric's distribution power poles, based on that of Harness (1997), which are outlined in Table 2.2. In most cases, poles that shared many characteristics with only minor modifications were categorized together for the sake of limiting the number of categories for analysis. Photos of most configurations can be found in Appendix A.

In total, all distribution structures within 21 oilfield and 18 rural sections were inventoried. The total number of poles within each category (or type) were summed and divided by the total number of sections inventoried to generate an average number of poles per category for both oilfield and rural sections (see Eq. 2.5).

Table 2.2. Power pole configuration classification system of ATCO Electric's structures

Configuration	Code	Description
1 PH Transformer[1]	**1XR**	One transformer, cutout, lightning arrestor and associated jumper wires mounted on a single PH pole
3 PH Transformer	**3XR**	Either three transformers or a single three PH transformer box, three cutouts and three lightning arrestors and associated jumper wires mounted on a 3 PH pole
1 PH Cutout	**1FU**	One cutout (fuse) and jumper wire mounted on a single PH pole
3 PH Cutout	**3FU**	Three cutouts and associated jumper wires mounted on a 3 PH pole
1 PH Deadend	**1DE**	One energized wire terminating on suspended insulators on a single PH pole with associated jumper wires; some have a second, neutral wire running parallel approximately 1.5-2.0m below energized wire
3 PH Deadend[2]	**3DE**	Three energized wires terminating on suspended insulators on a 3 PH pole with associated jumper wires; some have a fourth, neutral wire running parallel approximately 1.7m below energized wires
3 PH Modified Deadend	**3DEM**	See 3DE but also has either two conductors on one side of the crossarm or a directional change

Table 2.2 (con't). Power pole configuration classification system of ATCO Electric's structures

Configuration	Code	Description
1 PH Corner	**1CR**	Two single PH tangent structures intersecting (but not terminating) with jumper wires connecting them
3 PH Corner	**3CR**	Two- 3 PH tangent structures intersecting (but not terminating) with jumper wires connecting them; most have two conductors on one side of the lower crossarm, or some have a protruding metal brace supporting the central conductor
1 PH Tangent[3]	**1TG**	One energized wire supported on a pin-type insulator, mounted on a single PH pole; some have a second, neutral wire running parallel approximately 1.5-2.0m below energized wire; rarely, both wires are supported by a crossarm
3 PH Tangent[3]	**3TG**	Three energized wires supported on pin-type insulators, mounted on a 3PH pole; some have a fourth, neutral wire running parallel approximately 1.7m below energized wires
1 PH Recloser	**1RC**	One electronic recloser, two lightning arrestors and associated jumper wires mounted on a single PH pole
3 PH Recloser	**3RC**	Three electronic reclosers, multiple lightning arrestors and associated jumper wires mounted on a 3 PH pole
1 PH Double Deadend	**1DD**	Two single PH lines intersecting that each have one energized wire terminating on suspended insulators and one jumper wire connecting them
3 PH Double Deadend[2]	**3DD**	Two 3PH poles intersecting that each have three energized wires terminating on suspended insulators; the two poles are connected by a series of jumper wires
1 PH Regulator Bank	**1RB**	One regulator bank mounted on a platform with associated switches, jumper wires, and lightning arrestors
3 PH Capacitor Bank	**3CB**	Three capacitors, cutouts and lightning arrestors mounted on a three PH pole
3 PH Overhead to Underground Riser	**3UG**	Four wires (three energized, one neutral), three cutouts, three lightning arrestors and three stress cones mounted on 3 PH pole
3 Gang Switch	**3GA**	Three switches mounted on a 3 PH tangent structure; jumper wires connect each switch to a primary wire
Service Poles	**SP**	Shorter, low voltage (<1kV), tapped off customer service poles usually found immediately adjacent to 3XR structures

[1] PH = "phase", or energized wire

[2] In some cases, deadend structures were later modified to continue. This usually resulted in pin-type insulators mounted on the crossarm, with jumper wires making the connection between all insulators

[3] The description above of the 1TG and 3TG are of the typical tangent structures. Some modifications exist, however, that could potentially make them more dangerous to raptors. These modifications pertain to both 1PH and 3PH unless otherwise indicated (in parentheses): presence of a guy wire that leads to the pole top, presence of a ground wire running up the side of the pole, a metal crossarm, the presence of a lower voltage Rural Electrification Association (REA) line as a double circuit, a change in the direction of the line, two parallel crossarms instead of one (3PH), two insulators on one side of the crossarm (3PH), and a crossarm supporting both neutral and energized wires (1PH)

2.2.6. Statistical Analyses

When viewed from both temporal and spatial scales, raptor electrocution is a relatively rare event, resulting in a low probability of occurrence and thus making it comparable against a random Poisson distribution. The following analyses were performed using Microsoft Excel 2000 (Microsoft Corporation 1999).

Because one objective of this project was to produce an estimate of mortality as a function of time, the electrocution evidence found during the first surveys were not included in the analysis; those carcasses represented the mortality that occurred at a structure at any time up until the point of the survey.

2.2.6.1. Electrocution evidence surveys

When attempting to determine the extent to which various power pole configurations present a risk to raptors, it is important not only to quantify the number of kills recorded at each configuration type, but also to factor in the relative proportion those poles represent on the landscape (Harness and Wilson 2001). In this case, I used the relative proportion that each structure type represented of all the poles sampled.

In order to address the question of whether or not the rate of electrocution varies among structure configurations, the observed frequency of mortality was compared to the expected frequency. In order to do this, I first calculated the probability of electrocution (μ) which, based on the number of carcasses recovered, is defined as the number of raptors that should have been recovered at each individual pole sampled if each pole had an equal likelihood of electrocuting a raptor. This parameter was calculated using the formula:

$$\mu = \frac{TOTALDEAD}{TOTALPOLES}$$

where TOTALDEAD is the total number of electrocuted raptors found during the second survey and TOTALPOLES is the total number of distribution power poles sampled during the second survey. From this value, the expected frequency of electrocution for each pole category (λ_i) was calculated as follows:

$$\lambda_i = \mu * POLES_i$$

where $POLES_i$ is the total number of poles of category *i* sampled.

A Poisson distribution for each pole category was then generated using the following formula (Freund & Walpole 1987, p194):

$$p(x;\lambda) = \frac{\lambda^x e^{-\lambda}}{x!} \quad \text{for } x = 0, 1, 2\ldots. \qquad \text{[Eq. 2.1]}$$

Where x represents the Poisson random variable (Freund & Walpole 1987, p194), or in this study, it represents number of electrocuted raptors. Effectively, this created a probability distribution of finding x carcasses beneath each pole category and thus the observed frequency of mortality at each pole category could then be tested against the random Poisson distribution.

If the observed frequency of electrocution was lower than its associated λ_i, the p-value associated with the observation was calculated as follows:

$$p(\leq x \text{ carcasses at pole category } i) = \sum_i p(x) + p(x-1) + ... + p(0) \qquad \text{[Eq. 2.2]}$$

Similarly, if the observed frequency of electrocution was higher than its associated λ_i, the p-value associated with the observation was calculated as follows:

$$p(\geq x \text{ carcasses at pole category } i) = \sum_i p(x) + p(x+1) + ... + p(x+\infty) \qquad \text{[Eq. 2.3]}$$

The above calculations are based on performing a one-tailed test. In the situations where a two-tailed test was necessary (when a prediction as to whether the pole category would electrocute more or fewer birds than expected was not made prior to data collection), the methods were identical to Equations 2.2 and 2.3, with the exception that the p-value was doubled to make it a two-tailed test (Peter Blenis 2005, personal communication). Because of small sample sizes and also to be conservative from a conservation standpoint, the alpha value for these analyses was set at 0.10 to reduce the chances of making a Type II error, which can be far more costly in ecological studies (Johnson 1999).

2.2.6.2. Scavenger assessment

The percentage of chicken carcasses remaining was plotted against time since the carcasses were deposited to create a “carcasses remaining curve”. The area under this curve was divided by the equivalent number of days in the scavenger assessment that passed between the first and second electrocution evidence surveys. This represented the average probability of a carcass remaining on site and was used as the factor for correcting the electrocution evidence surveys to account for loss to scavengers.

2.2.6.3. Total mortality estimates across the study area

The estimates of mortality across the broad study area are based on evidence collected during the electrocution surveys, corrected for loss to scavengers using the calculated average probability of a carcass remaining on site. This study area also includes the ATCO Electric service district of Castor, as it is situated between Stettler, Forestburg and Consort. Including this area results in a mortality estimate that spans a broad, continuous area of the province. Detailed coordinates of the broad study area can be found in Chapter 3.

Since most sampling was conducted in oilfield areas but the broader study area contains both oilfield and rural areas, estimated proportions of these respective areas were necessary to estimate mortality beyond just the sampled areas. I generated these proportions by ocular estimates of 1:40 000 and 1:20 000 maps of the entire study area that were provided by ATCO Electric. The proportions of oilfield and rural areas as well as regions containing no power poles were estimated for the 143 townships within the study area. These proportions were then summed and averaged over the entire study area, and converted into the equivalent number of townships that each proportion represented (see Appendix B for more detail). Calculating the mortality rate at each individual pole of each category and multiplying by the average number of poles of each category found in each density then provided total mortality estimates. Areas lacking poles were not included in the calculations below; however, they were still taken into account when the equivalent number of townships were calculated, and thus were incorporated into the final mortality estimates. An example of the following calculations can be found in Appendix B.

These estimates are based on a series of calculations, where:
i = pole category; *j*= area density category (oilfield or rural)

1. $$MRATE_i = \frac{NO.DEAD_i}{POLES_i} \qquad \text{[Eq. 2.4]}$$

Where $MRATE_i$ = mortality rate for each individual pole of a given category *i*; $NO.DEAD_i$= number of electrocuted birds found at category *i*; and $POLES_i$= the total number of poles of category *i* sampled.

2. $$AVG.DENS_{ij} = \frac{INV_{ij}}{SEC_j} \qquad \text{[Eq. 2.5]}$$

Where $AVG.DENS_{ij}$= the average density of poles of category *i* on the landscape in *j*-density category; INV_{ij} = the total number of poles of category *i* counted during inventory in all *j*-density categories; and SEC_j = the number of sections inventoried in the *j*-density category.

3. $\text{DEAD.SEC}_{ij} = \text{AVG.DENS}_{ij} * \text{MRATE}_{i}$ [Eq. 2.6]

Where DEAD.SEC_{ij} = estimated number of raptors killed on all structures of category *i* per *j*-density section.

4. $\text{DEAD.TWP}_{ij} = \text{DEAD.SEC}_{ij} * 36$ sections/township [Eq. 2.7]

Where DEAD.TWPij = estimated number of raptors killed on all structures of category *i* per *j*-density township.

5. $\text{DEAD.SA}_{ij} = \text{DEAD.TWP}_{ij}$ * number of equivalent *j*-density townships in the entire study area [Eq. 2.8]

Where DEAD.SA_{ij} is the estimated number of raptors killed on poles of category *i* in the equivalent number of *j*-density townships (equivalent number of townships calculated as in Appendix B) within the entire study area, and

6. $$\text{TOTAL.DEAD} = \sum_{j=1}^{2} \sum_{i=1}^{15} DEAD.SA_{ij}$$ [Eq. 2.9]

Where TOTAL.DEAD is the total estimated number of raptors killed by electrocution on all categories of poles over the entire study area.

2.3. Results

2.3.1. Electrocution Evidence Surveys

During the course of this research, I sampled each of 379 distribution power poles twice. During the first survey at each pole, the partial or complete remains of nine raptors were discovered, including two red-tailed hawks, two great horned owls, one golden eagle, and five unidentified raptors. Only one raptor, a great horned owl, was confirmed electrocuted. These data were not included in the analyses.

During the second checks at each pole, the remains of six confirmed electrocuted raptors were discovered. The remains of fourteen additional raptors were found but were not confirmed as electrocutions. Structures under which carcasses were found are listed in Tables 2.3 and 2.4. Of the six confirmed electrocutions, three had existing bird protection in the form of insulation on the transformer lead wires and/or bushing caps.

An additional 73 non-raptor carcasses were found (7 confirmed electrocuted, 66 unconfirmed) over the course of the entire sampling period including common raven, sharp-tailed grouse (*Tympanuchus phasianellus*), northern flicker (*Colaptes auratus*), rock pigeon (*Columba livia*), and many others that were not identifiable to species due to the small quantity of remains found. These non-raptor species were not included in the analyses. All data from the electrocution evidence surveys can be found in Appendix D, Table D1.

Table 2.3. Confirmed great horned owl (GHOW) and red-tailed hawk (RTHA) electrocutions and associated structures. Categories as described in Table 2.2 (n=6).

Structure	Species
3XR	(1) GHOW
3XR	(3) RTHA
3DEM	(1) GHOW
3DD	(1) RTHA

Table 2.4 Unconfirmed electrocutions by species, and associated structures. Categories as described in Table 2.2 (n=14).

Structure	Species
3XR	(3) GHOW
3XR	(3) RAPTOR
3DE	(3) GHOW
3DE	(1) RTHA
SP	(1) GHOW
SP	(1) RTHA
SP	(1) RAPTOR
1DD	(1) RAPTOR

The proportions of both confirmed and unconfirmed electrocutions were not consistent with that which was expected based on the proportion of structure types sampled. For example, three-phase transformer structures represented 67% of confirmed electrocutions, while only representing 30% of the poles sampled. Conversely, three-phase tangents represent 15% of structures sampled but no confirmed electrocutions were discovered beneath these structures (Figures 2.2 and 2.3).

No significant differences were noted in mortality rate among structure categories when compared using solely confirmed electrocutions (Table 2.5). When the same comparison was made using both confirmed and unconfirmed electrocutions combined, three-phase transformers and single-phase double deadends electrocuted significantly more raptors than expected ($p=0.085$ and 0.051, respectively), while three-phase tangents were responsible for significantly fewer raptor electrocutions than was expected ($p=0.049$) (Table 2.6).

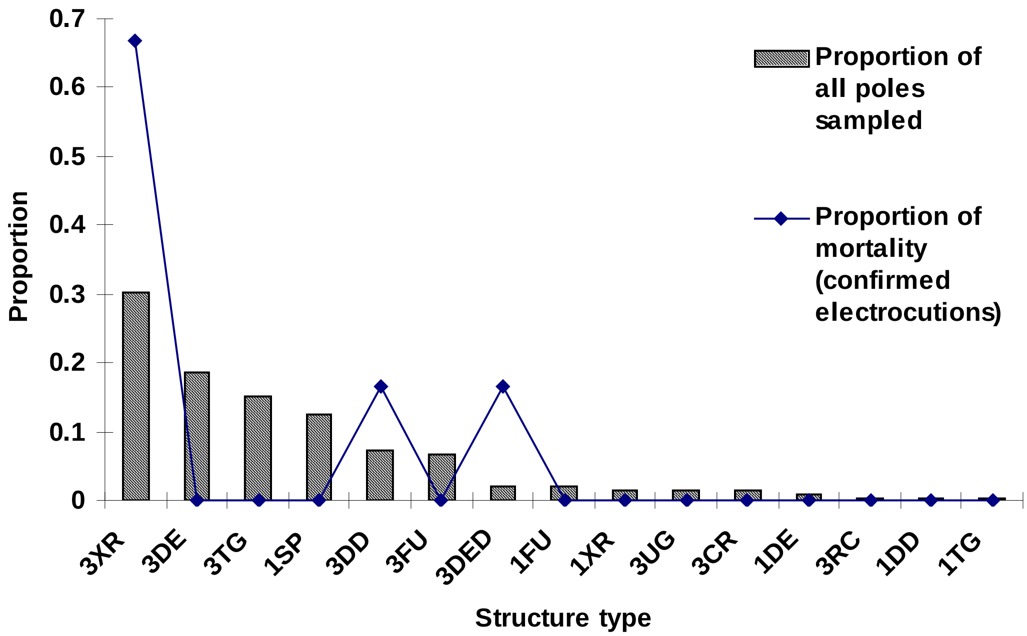

Figure 2.2. Proportion of confirmed electrocution mortality as a function of the proportional frequency of each category sampled (based on categories described in Table 2.2) (n=379 poles; n=6 confirmed mortalities).

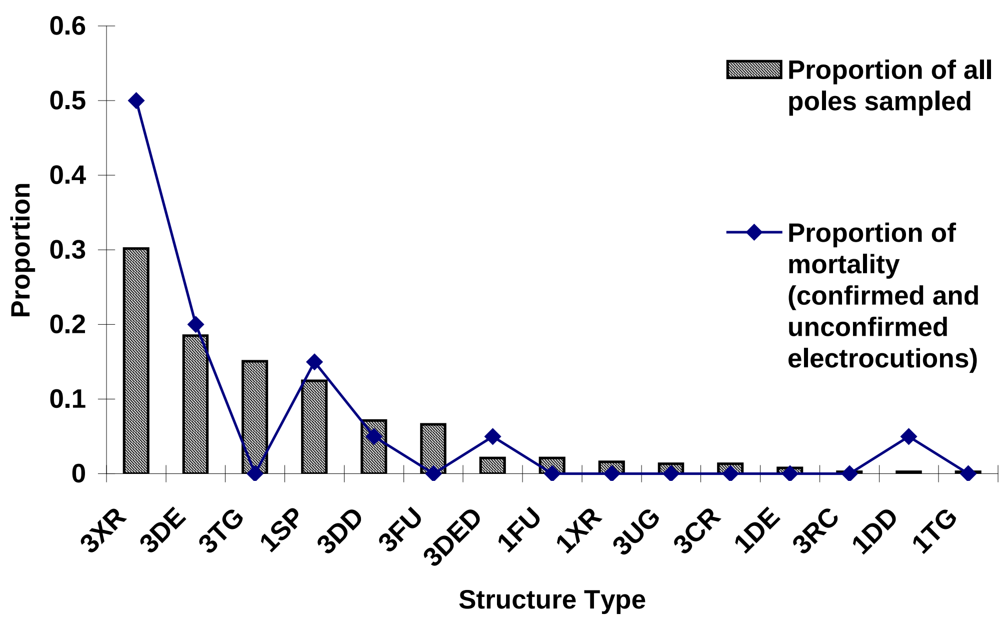

Figure 2.3. Proportion of confirmed and unconfirmed electrocution mortality as a function of the proportional frequency of each category sampled (based on categories described in Table 2.2) (n=379 poles; n=20 confirmed and unconfirmed mortalities).

Table 2.5. Probability levels for nonrandom distribution of confirmed electrocution fatalities (n=6) per structure type, and associated expected number of fatalities per structure type. Expected numbers were generated based on the observed number of mortalities. Data were tested against the Poisson distribution with p = probability of making a Type 1 error for H_0: no difference in mortality rates among structures. Tests were one-tailed unless denoted by (*), indicating a two-tailed test. Categories as described in Table 2.2.

Structure Type	Number of poles sampled	Observed Electrocutions	Expected Electrocutions	p-value
1XR	6	0	0.095	0.909
3XR	114	4	1.805	0.110
1FU	8	0	0.127	0.881
3FU	25	0	0.396	0.673
1DE	3	0	0.063	0.939
3DE	70	0	1.108	0.330
3DEM	8	1	0.127	0.119
3CR	5	0	0.079	0.924
1TG	1	0	0.016	0.984
3TG	57	0	0.902	0.406
3RC	1	0	0.016	0.984
1DD	1	0	0.016	0.984
3DD	27	1	0.427	0.348
3UG	5	0	0.079	0.924
*SP	47	0	0.744	0.950

Table 2.6. Probability levels for nonrandom distribution of combined confirmed and unconfirmed electrocution fatalities (n=20) per structure type, and associated expected number of fatalities per structure type. Expected numbers were generated based on the observed number of mortalities. Data were tested against the Poisson distribution with p = probability of making a Type 1 error for H_0: no difference in mortality rates among structures. Tests were one-tailed unless denoted by (*), indicating a two-tailed test. Bolding indicates significance. Categories as described in Table 2.2.

Structure Type	Number of poles sampled	Observed Electrocutions	Expected Electrocutions	p-value
1XR	6	0	0.317	0.729
3XR	114	10	6.016	**0.085**
1FU	8	0	0.422	0.656
3FU	25	0	1.319	0.267
1DE	3	0	0.211	0.810
3DE	70	4	3.694	0.505
3DEM	8	1	0.422	0.344
3CR	5	0	0.264	0.768
1TG	1	0	0.053	0.949
3TG	57	0	3.008	**0.049**
3RC	1	0	0.053	0.949
1DD	1	1	0.053	**0.051**
3DD	27	1	1.423	0.828
3UG	5	0	0.264	0.768
*SP	47	3	2.480	0.902

2.3.2. Scavenger Assessment

Chicken carcasses were steadily removed for the first seven days, and slowly continued to disappear until leveling off on day 35 (Figure 2.4). By the seventh day, scavengers had removed almost half (48%) of the carcasses. Corpses placed beneath poles with suspected large mammal burrows were removed at a slightly faster rate, as illustrated in Figure 2.5. No attempt was made to determine which species were involved in scavenging carcasses.

On average, 43 days elapsed between the first and second surveys at each pole during electrocution evidence surveys. Thirty-eight percent (19 chickens) of the original carcasses were still detectable (>5% remaining) after 43 days; however, it is important to note that all 50 carcasses had been heavily scavenged, and the 19 remaining on site were reduced to skeletal remnants. The average probability of a carcass remaining on site was calculated as 47%. Assuming the loss rate of raptor carcasses by scavengers is the same as that for chicken carcasses, evidence found during the second electrocution evidence surveys were calculated to represent 47% of raptor mortality that occurred since the first round of checks. Data from the scavenging assessment can be found in Appendix D, Table D2.

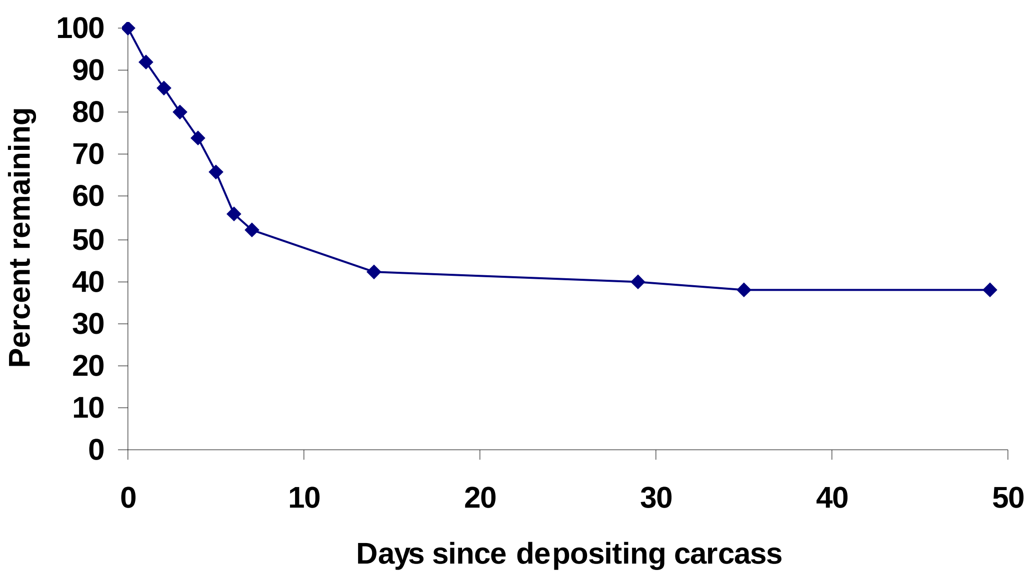

Figure 2.4. Percentage of chicken carcasses remaining on site up to 7 weeks after being deposited (n=50). Carcasses were considered scavenged when less than 5% was remaining.

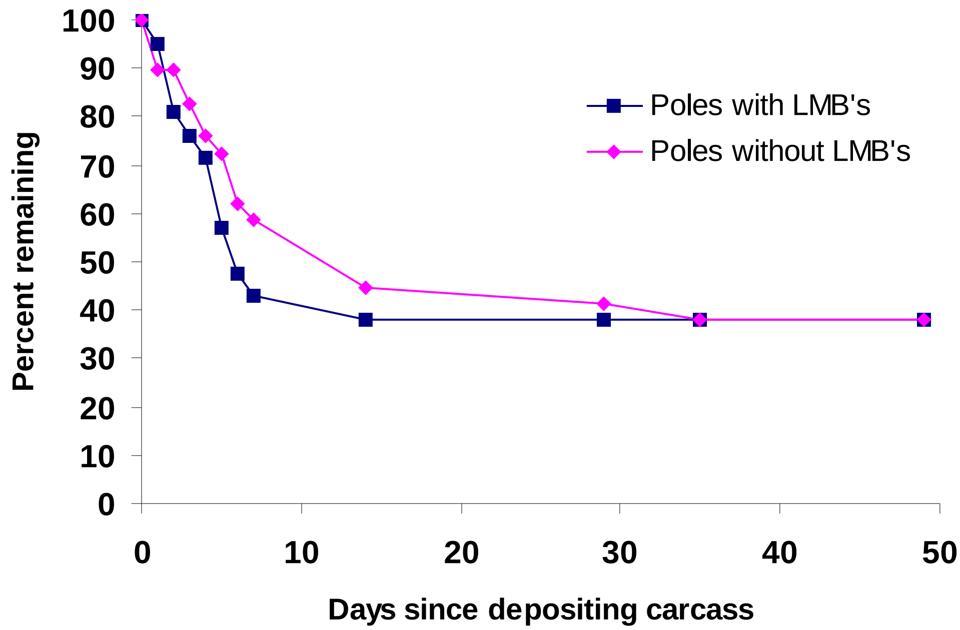

Figure 2.5. Comparison of the rate at which carcasses were scavenged at poles with and without suspected large mammal burrows (LMB's) within a 10m radius of the pole (n=21 with LMB's and n=29 without LMB's).

2.3.3. Pole Inventory

Three-phase tangent structures and single-phase tangent structures are by far the most numerous in both the oilfield and rural areas, respectively. In the latter case, they constitute more than half of the structures on the landscape. The proportional frequencies and average number of poles of each category in both oilfield and rural areas are shown in Table 2.7. Gang Switch structures are very rare in the power system and were not encountered in the 39 sample sections inventoried.

The mean number of poles per section was generated by dividing the total number of poles inventoried for each category by the total number of sections of that density sampled. For example, 12 single-phase transformer (1XR) poles were inventoried in 21 oilfield sections; therefore, the mean number of poles per oilfield section is 0.571. Inventory data can be found in Appendix D, Table D3.

Table 2.7. Proportional frequencies of power poles on the landscape and the average number of poles of each category per oilfield and rural sections. Structures are ordered from most common to least common within each section. Information is based on pole inventory (n=1254 and n=449 poles in oilfield and rural sections, respectively).

	OILFIELD			RURAL	
Structure category	**Proportional frequency**	**Mean number of poles/section**	**Structure category**	**Proportional frequency**	**Mean number of poles/section**
3TG	0.377	22.524	1TG	0.608	15.167
SP	0.159	9.524	1DE	0.100	2.500
3XR	0.152	9.095	3TG	0.098	2.445
3DE	0.128	7.619	1XR	0.078	1.944
3DD	0.043	2.571	SP	0.047	1.167
1TG	0.042	2.523	1FU	0.027	0.667
3FU	0.035	2.095	1DD	0.022	0.556
3UG	0.016	0.952	3FU	0.007	0.167
1DE	0.011	0.667	3XR	0.002	0.056
1XR	0.010	0.571	3DEM	0.002	0.056
1FU	0.009	0.524	1CR	0.002	0.056
3DEM	0.008	0.476	1RC	0.002	0.056
3CR	0.006	0.333	3CB	0.002	0.056
1DD	0.002	0.143	3DD	0.002	0.056
1RB	0.001	0.048	3DE	0.000	0.000
3RC	0.001	0.048	3CR	0.000	0.000
1CR	0.000	0.000	3RC	0.000	0.000
1RC	0.000	0.000	1RB	0.000	0.000
3CB	0.000	0.000	3UG	0.000	0.000
3GA	0.000	0.000	3GA	0.000	0.000
TOTAL	**1.000**	**59.714**	**TOTAL**	**1.000**	**24.945**

2.3.4. Total Mortality Estimates

Tables 2.8 and 2.9 display the number of raptor electrocutions found beneath each category of structure corrected for scavenging pressure. Minimum estimate values are based on confirmed electrocution data, while maximum estimate values are based on the combination of confirmed and unconfirmed electrocutions. As seen in Table 2.10, 542-2762 raptors are estimated lost to electrocution in the entire study area over a six-week period spanning June – August.

Table 2.8. Total number of raptor electrocutions recovered in sampling areas during surveys, and corrected for scavenging pressure (in parentheses). The latter is based upon 47% of carcasses recovered after 43 days during scavenging assessment. Also reported are the associated minimum and maximum mortality rates at each individual pole of each category, and rates adjusted for scavenging (in parentheses). Mortality rate is expressed as the number of raptors killed per individual pole in each category over a 6-week (43 day) period spanning June-August.

Structure Category	Confirmed Electrocutions	Confirmed and unconfirmed electrocutions combined	Minimum mortality rate	Maximum mortality rate
1XR	0 (0)	0 (0)	0 (0)	0 (0)
3XR	4 (8.5)	10 (21.3)	0.035 (0.075)	0.087 (0.187)
1FU	0 (0)	0 (0)	0 (0)	0 (0)
3FU	0 (0)	0 (0)	0 (0)	0 (0)
1DE	0 (0)	0 (0)	0 (0)	0 (0)
3DE	0 (0)	4 (8.5)	0 (0)	0.057 (0.122)
3DEM	1 (2.1)	1 (2.1)	0.125 (0.266)	0.125 (0.266)
3CR	0 (0)	0 (0)	0 (0)	0 (0)
1TG	0 (0)	0 (0)	0 (0)	0 (0)
3TG	0 (0)	0 (0)	0 (0)	0 (0)
3RC	0 (0)	0 (0)	0 (0)	0 (0)
1DD	0 (0)	1 (2.1)	0 (0)	1.000 (2.13)
3DD	1 (2.1)	1 (2.1)	0.037 (0.097)	0.037 (0.079)
3UG	0 (0)	0 (0)	0 (0)	0 (0)
SP	0 (0)	3 (6.4)	0 (0)	0.064 (0.136)

Table 2.9. Estimated range of raptor mortality within each structure category per section (2.59km^2) over a 6-week (43 day) period during June-August. Estimates have accounted for scavenging pressure.

Structure Category	Mortality rate for oilfield sections (min-max)	Mortality rate for rural sections (min-max)
1XR	0	0
3XR	0.68 – 1.70	0 – 0.01
1FU	0	0
3FU	0	0
1DE	0	0
3DE	0 – 0.93	0
3CR	0	0
1TG	0	0
3TG	0	0
3RC	0	0
1DD	0 – 0.01	0 – 0.05
3DD	0.20 – 0.20	0.004 – 0.004
3DEM	0.13 – 0.13	0.01 – 0.01
3UG	0	0
SP	0 – 1.29	0 – 0.16
TOTAL	**1.01 – 4.26**	**0.02 – 0.23**

Table 2.10. Total estimate of raptor mortality over entire study area (13 400 km^2) including the ATCO Electric service districts of Stettler, Castor, Consort and Forestburg over a 6-week (43 day) period spanning June-August.

Structure Category	Minimum Estimate	Maximum Estimate
1XR	0	0
3XR	324	811
1FU	0	0
3FU	0	0
1DE	0	0
3DE	0	423
3DEM	110	110
3CR	0	0
1TG	0	0
3TG	0	0
3RC	0	0
1DD[1]	0	160
3DD	108	108
3UG	0	0
SP	0	1150
TOTAL	**542**	**2762**

[1]this value has been scaled down from the original. Because one unconfirmed body was found under the only 1DD sampled, this produced a 100% mortality rate across the landscape, which is likely not an accurate reflection of true mortality. Instead, the mortality rate at the three-phase version of that structure (3DD) was substituted as the value in calculations

2.4. Discussion

2.4.1. Lethal Structures

When only data on confirmed raptor electrocutions were analyzed, no significant differences were found in mortality rates among pole configurations. This is not surprising given that only six occurrences of electrocution were confirmed. When examined from the perspective of the percentage of poles where confirmed mortalities were discovered (1.6%), these results were slightly lower than a similar study reporting 2.0% of poles with confirmed mortalities (Liguori 2003). Nonetheless, three-phase transformers and three-phase modified deadends displayed a slight difference from expected mortality rates, albeit not significant.

Conversely, when the data collected on unconfirmed electrocutions were included in the analyses, three-phase transformer structures and single-phase double deadends appeared to be more lethal to raptors than was expected if all poles had an equal chance of electrocuting a raptor, while three-phase tangent structures electrocuted fewer raptors than would be expected. These results were consistent with predictions made prior to collecting data. However, given that these conclusions were drawn from data that were not based solely on confirmed electrocutions, some caution must be exercised in interpreting these results.

Inherent to statistical testing is the fact that small sample sizes decrease the sensitivity of a test (Townend 2003), because of the diminished capacity detect a difference, if one indeed exists. Although 379 power poles were studied, some poles occur less frequently in oilfields, which resulted in inadequate representation of those poles in the analyses. For example, single-phase deadends and double deadends, single-phase tangents, three-phase reclosers, and three-phase overhead to underground risers were each represented by five or fewer poles. This proved especially problematic for analyzing single-phase double deadends, where an unconfirmed electrocution was discovered under the only pole of that category sampled. Consequently, the mortality rate for that pole category was calculated at 100%, thereby artificially inflating the true mortality estimate. Instead, for the purpose of the total mortality estimate, the mortality rate at the three-phase double deadends was used.

It should be noted that structures classified as service poles are of much lower voltage (often 480v) than most distribution structures, and often support insulated wires. This voltage also falls far below the level found to be dangerous to eagles with wet feathers (Nelson 1980) and are generally considered raptor-safe structures (APLIC 1996). However, Nelson (1980) noted an eagle convulsed at 400v during testing of skin-to-skin contacts. Although unlikely, the potential may exist for a larger reaction to the same voltage from a smaller raptor such as an owl or hawk, especially on uninsulated service poles.

However, the more likely explanation for the evidence found beneath service poles is that they are usually in close association with three-phase transformers, even within the 10m radius of the latter in most circumstances. In some cases, the random number table dictated a service pole to be sampled, but not the three-phase transformer structure that was within 10m of the service pole. Consequently, three-phase transformer structures may have been responsible for some or all of the remains discovered beneath service poles during the surveys.

2.4.2. Biases: Detection, Habitat and Crippling

As mentioned earlier, Beaulaurier (1981) recommended correcting the mortality estimate for four biases: detection, removal, habitat, and crippling. Only removal bias was used as a correction factor in this research. Since the primary goal of the electrocution evidence surveys was to assess the differences in mortality rates among structure configurations, it was assumed that the searchers' ability to detect carcasses would remain constant among structure types; hence, accounting for detection bias was deemed unnecessary with respect to the primary goal. Furthermore, the notion of performing such a test was not considered until the following summer season, by which point only one searcher was available.

The three sampling sites were relatively homogenous in the flat, open terrain and the amount of water found beneath the poles was sufficiently inconsequential to warrant a separate investigation of habitat bias. Finally, Beaulaurier (1981) recommended testing for the crippling bias within the context of dead bird searches for casualties of power line collision, where presumably the radius in which the bird might fall is substantially larger given the velocity with which a bird is traveling when it collides with a line. However, while birds (especially prey species) that initially survive a collision might be apt to move out of the search zone to find cover, this is likely less common in electrocution cases. Since electrocuted raptors are typically found close to the base of a pole, I am confident that the 10m radius searched during the electrocution surveys is of sufficient size for finding an electrocuted raptor, and is substantially larger than that searched by others (Pearson et al. 2000; Harness 2000b; Liguori 2003; Dwyer 2004).

2.4.3. Scavenger Assessment

The observed 62% total scavenging efficiency over 6 weeks noted in this assessment was somewhat lower than other reported values. Comparison between scavenging studies is difficult since the species of experimental carcasses used and the duration of each study varies. Nonetheless, a review of multiple studies that measured carrion removal across various regions and climates found that an average of 75% of available carcasses were removed by vertebrate scavengers, however the durations of these studies varied from 24 hours to several months (DeVault et al. 2003).

Instead of viewing the results from a total scavenging efficiency standpoint, it is likely more appropriate to examine the data using the average probability of carcasses remaining. The former method assumes that all of the raptor remains recovered were from birds electrocuted the day following the first check of the pole. The average probability method incorporates birds that would have been electrocuted at any point between the first and second surveys. This study suggests that electrocuted raptors found during the second survey of each pole likely represents 47% of the true number of raptors electrocuted since the previous check (6 weeks). In comparison, Ferrer et. al. (1991) estimated that after one month, raptor carcasses recovered represented only 37% of total raptors electrocuted during that time. Thus, the scavenging rate in this research was lower than that particular study, however, as explained above, direct comparisons between studies are difficult.

Nonetheless, the scavenging assessment in this region indicates that casualties of electrocution may be an important source of carrion for scavengers. Houston (1979) remarked that carrion consumed by scavengers is rarely that of a predator kill, since predators are apt to consume their entire kill, or minimally be fiercely protective of it. As a consequence, obligate, and to a lesser degree, facultative scavengers probably rely more heavily on mortality due to other causes such as disease, exposure, malnutrition, or accidents (DeVault et al. 2003). This reliance may be particularly strong in more northerly climates.

Caution should be used before extrapolating the scavenging pressure results beyond the region in which this experiment took place. Many factors contribute to scavenger efficiency including temperature, visibility and density of carcass, carcass size, habitat type and amount of vegetative cover (Balcomb 1986; Linz et al. 1991; DeVault et al. 2003). Presumably, species composition of scavengers would also influence their efficiency: carrion consumption by highly territorial scavengers that do not roam large distances would likely be minimal, as the chance of finding carrion is proportionately related to distance traveled by the scavenger (DeVault et al. 2003). Additionally, open habitats, such as that where this experiment was undertaken, likely enable scavengers to find baited carrion more readily. This would be especially true of large raptors such as red-tailed hawks and turkey vultures, that may be more successful at locating carrion on the wing, where their visual perception is more effective than in more structurally complex habitats such as forests (DeVault et al. 2003). Finally, the chicken carcasses were white, which would presumably make them more conspicuous to scavengers that rely more heavily on sight than scent, as compared to the more cryptic coloration of raptors.

2.4.4. Total Mortality Estimates

While total loss is estimated at 1.01 – 4.26 and 0.02- 0.23 raptors per section in oilfield and rural areas respectively, these numbers increase dramatically when the entire study area is considered. An estimated 542 - 2762 raptors are lost to electrocution in the study area over a six-week period spanning June – August. Based on the 143 townships and over 5000 sections in the study area, the abovementioned total mortality estimates can be converted to an “average” rate of 3.77 – 19.22 electrocuted raptors per township and 0.11-0.53 electrocuted raptors per section.

There are three things to consider when interpreting these results. First, because the minimum total mortality estimate is derived from only confirmed electrocutions, the difference between the minimum and maximum estimates then stem solely from the unconfirmed electrocutions. However, for these cases, remains found were too sparse to ascertain the cause of death. Other possible sources of mortality include disease, shooting, inter- or intraspecific competition, or even hydrogen sulfide (H_2S) poisoning from the oilfields (Franson and Little 1996). Furthermore, in some of these unconfirmed cases only feathers were discovered, thus I could not say with certainty that they represented a dead bird: the possibility exists that they fell from a live bird (for example during preening or a fight with another bird).

Second, despite the fact that all remains (confirmed and unconfirmed) discovered during the first check were removed to prevent double counting, there exists the possibility that some of the remains found (especially if there were only a few burnt feathers) were on site during the first check but were inadvertently overlooked by the searchers.

Finally, I speculate that the accuracy of any total mortality estimate is inversely proportional to the size of area to which one wishes to extrapolate. Characteristics such as topography, land use, prey concentrations and distribution, scavenging pressure, and raptor species composition and density are apt to vary within the broad study area. The assumption that all of these factors remain constant has the potential of reducing the accuracy of the estimate of total raptor loss to electrocution. Given the above three considerations, a conservative estimate of electrocution mortality is likely most appropriate.

2.4.5. Summary

A review of this chapter's objectives and the associated findings are presented here.

1) *Determine the proportion of mortality at each structure type as it relates to its abundance on the landscape.*

Three-phase transformer poles represented 67% of confirmed mortality, but only represented 30% of poles sampled, and 15% of poles on the landscape. Conversely, while three-phase tangent structures comprised 15% of poles sampled and 37% of poles on the landscape, no electrocutions were found beneath these structures. Details for the remaining structure categories can be found in Figures 2.2, 2.3 and Table 2.7.

2) *Quantify the effect of scavenging pressure on the ability to recover electrocuted birds.*

After 6 weeks, only 38% of chicken carcasses were still detectable. The average probability of a carcass remaining on site after 6 weeks was 47%. Furthermore, every experimental carcass had been scavenged to some degree.

3) *Calculate the estimated rate of non-reported raptor electrocution per section (2.59 km^2) over 6 weeks in the breeding season.*

Total loss is estimated at 1.01 – 4.26 and 0.02 – 0.23 raptors per section in oilfield and rural areas, respectively. This translates to 0.11 - 0.53 raptors lost per “average” section in the study area.

4) *Obtain the total estimate of non-reported raptor electrocution mortality across the study area after the effects of scavengers are taken into account.*

An estimated 542 - 2762 raptors are lost to electrocution in the study area over a six-week period in the breeding season.

In summary, I found no significant differences in raptor mortality among configuration types based solely upon discoveries of the six confirmed electrocutions during field surveys. This is likely due to the small sample size from which comparisons were made. However, when these data were combined with that of unconfirmed electrocutions, three-phase transformer bank structures and single-phase double deadend structures were found to cause significantly higher raptor mortality. Conversely, three-phase tangent structures were responsible for disproportionately fewer electrocutions relative to their occurrence within poles sampled. Results also demonstrate that scavengers can have a sizeable impact on the ability of the investigator to find carcasses after 6 weeks.

These results suggest that a substantial number of electrocutions may occur that do not cause power outages, and that the extent of raptor mortality on power lines is likely being underestimated by the utility.

It is important to note that the mortality rates and scavenging rates expressed in this project only represent a six-week period in the summer season in relatively flat, open habitat. Results should not be extrapolated beyond the spatial and temporal scope of this study. All large diurnal raptors in the study area migrate in the fall, and subsequent electrocution mortality rates over the winter would likely decrease. While there are some large raptor species that may migrate from further north to over-winter in the study area, no electrocutions of any additional species were reported during the course of this project (see Chapter 3). Additionally, dramatically fewer raptors would likely be lost to electrocution in forested regions because the proportion of potential perches represented by power poles is much smaller.

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Chapter 3: Patterns of electrocution across structure types, species, and demographic parameters as reported by ATCO Electric and from anecdotal accounts

3.1. Introduction

The overall probability of an electrocution occurring is a function of many factors, including those that are biological, environmental and technical. Technical influences were discussed in Chapter 2, and biological and environmental factors are examined in more depth here.

3.1.1. Biological Factors

3.1.1.1. Species

Not all species of raptors are equally susceptible to electrocution. In general, species inhabiting forested or more structurally complex landscapes rarely fall victim to this source of mortality (Benson 1981; Liguori 2003). Trees provide natural perching structures, rendering power poles less valuable to these birds, effectively reducing time that birds are exposed to this hazard. Therefore, species that occur in relatively treeless areas with low topographic relief are more susceptible to electrocution. Even within species in open ecosystems, many behaviors influence the risk of electrocution. For example, ground-nesting raptors such as the northern harrier are less vulnerable to electrocution (Janss 2000) as compared to many buteos, that frequently hunt from and nest on utility structures. Avian predators such as falcons often constitute a low percentage of mortality, but are certainly not immune to the risk (Harness 1997; Liguori 2003).

In general, the larger a raptor, the greater probability it has of completing the electrical connections with two parts of the body. Contacts between electrical currents can be made using the feet, bill, wrists, or even feathers under wet conditions. In a series of trials measuring conductivity of various components of a golden eagle's body, Nelson (1980) discovered that a dry feather is as insulative as air up to 70 000v. Although lethal voltages were not determined, the study also demonstrated that the eagle convulsed at only 400v when electrodes were attached to the fleshy part of each wrist (Nelson 1980), suggesting that skin-to-skin contact could prove deadly at relatively low voltages. Therefore, distances in excess of an eagle's span between wrists are the standard on which minimal clearances on "safe" structures are based. The Avian Power Line Interaction Committee (1996) has published a number of design considerations and retrofitting options for maintaining a 60-inch (1.52m) clearance between any two energized components or between energized and grounded components. This 60-inch minimum is sufficient to protect wrist-to-wrist contact of a large female golden eagle (Olendorff et al. 1981). Wrist-to-wrist measurements of non-eagle raptors are largely unpublished, and will be discussed in Chapter 5.

3.1.1.2. Age

Studies have shown that the age of a bird can influence its vulnerability to electrocution, especially within eagles. One study found 98% of 300 eagle electrocutions were fledglings (Nelson and Nelson 1976). Many authors have noted a higher rate of mortality among juveniles as compared to adults (Boeker and Nickerson 1975; Benson 1981; Ferrer and Hiraldo 1992; Dawson and Mannan 1995; Harness and Wilson 2001). This is generally thought to result because the juveniles are inexperienced in landing on, and maneuvering around, a structure. In a series of trials conducted by Nelson and Nelson (1976), trained golden eagles of various ages were filmed landing on and taking off of non-energized, mock power structures. While adults opted to approach the crossarm from below the conductors and tuck in their wings just prior to landing, the immature birds approached from above, which involved substantially more flailing of the wings. This added movement around live wires increases the chance that an electrocution will occur. Thus, fledging and dispersing birds are highly susceptible to electrocution (Benson 1981; Sergio et al. 2004).

Additionally, adult and juvenile golden eagles have been observed utilizing differing hunting techniques. Juveniles tend to rely more heavily on "still hunting", making multiple short flights from pole to pole and repeatedly returning to power structures after unsuccessful hunting attempts (APLIC 1996). This method is more energetically efficient than hunting on the wing, especially in colder temperatures (Benson 1981); it has also been noted as the most efficient hunting technique for red-tailed hawks (Orde and Harrell 1977) and ferruginous hawks (Wakeley 1978). Meanwhile, adults tend to hunt on the wing (Benson 1981), relying less on power poles and more on experience, thereby reducing the opportunity to contact live wires.

The phenomenon of a higher proportion of juveniles electrocuted than adults observed for eagle mortalities does not necessarily hold true for other species. Benson (1981) found that of the 16 non-eagle mortalities that could be aged, over half were adults. Furthermore, 70% of raptors killed on power lines in Spain were adults (Ferrer et al. 1991). This seemingly contradicting evidence in the literature has much to do with the temporal and spatial considerations of specific research projects. The proportion of adults and juveniles electrocuted during the course of a study is influenced heavily by the time of year, and whether or not the study is conducted on a species' migration, breeding, or wintering grounds.

3.1.1.3. Sex

Sex plays an important role in susceptibility to electrocution; raptors exhibit reversed sexual dimorphism, or RSD, such that females are larger than males. This increased size renders female raptors more vulnerable (Ferrer and Hiraldo 1992; Dawson and Mannan 1995).

3.1.1.4. Seasonal activities

Behaviors present during various stages of the year contribute to the susceptibility to electrocution. In breeding areas, activities surrounding the nesting season such as courtship and mating, nest building, territory defense, additional hunting trips, acquisition of flying and hunting skills, and juvenile dispersal all increase exposure time and activity around power structures. Benson (1981) reported that 46% of non-eagle deaths occurred during the nesting season. Similarly, Harness & Wilson (2001) reported most hawk and owl electrocutions in late summer. In wintering areas, raptors are often found in higher densities as they congregate in areas with high prey abundance, and rely more heavily on perch hunting (Benson 1981). Therefore, areas which serve as wintering grounds for raptors will experience higher electrocution mortality during this period (Miller et al. 1975). Annual migration may also influence local electrocution rates, especially in areas where certain species are only present at particular times of the year.

3.1.2. Environmental Factors

3.1.2.1. Climatic conditions

Climatic conditions play a large role in electrocutions. Under extremely wet conditions, wooden poles can become saturated with water and may become grounded (Harness 1997). Under such conditions, a bird would need only to sit on either the crossarm or pole top and touch one conductor for an electrocution to ensue. Furthermore, the birds' feathers themselves are more conductive when wet: Nelson (1980) discovered that wet feathers conducted electricity at only 5000v, as opposed to the 70 000v threshold for dry feathers. Saturated feathers may also make maneuverability around poles more difficult and spreading wings in an attempt to dry off is a behavior that may also put raptors at higher risk (Nelson 1980). Benson (1981) postulated that snow might pose an even greater threat than rain in this respect due to its propensity to melt into feathers, rather than roll off.

Because raptors tend to approach a pole in the direction of the prevailing wind, the orientation of the crossarm with respect to the prevailing wind is also very important, with those mounted perpendicular to the wind being the safest. If the crossarm is mounted parallel or diagonal to the wind, there is a higher risk of a raptor contacting conductors when landing or taking off from the structure, (Nelson and Nelson 1976; Benson 1981), as they must cross over conductors to land on the crossarm.

3.1.2.2. Habitat characteristics

Electrocution is much more prominent in grasslands and shrub lands (Kochert and Olendorff 1999) where raptors adapted to open country readily use the perching opportunities that power poles provide. Poles that offer the greatest view of the surrounding terrain, such as those located on hilltops and ridges, provide birds of prey with a hunting advantage and thus are more likely to be responsible for electrocutions because of their frequent use (Boeker and Nickerson 1975; Benson 1981). Although electrocution does occur in urban environments (Dwyer 2004), it is more common in rural areas with less human infrastructure (Ferrer et al. 1991).

Landscape characteristics such as vegetation, topographic relief, and land use also influence frequency of electrocutions, primarily because they influence the abundance of prey species in any area. Although not statistically significant, Benson (1981) discovered a higher occurrence of mortality beneath structures in natural areas adjacent to cultivated lands when compared to those further away. Furthermore, significant differences were found in raptor mortality in areas with different prey composition (Benson 1981).

3.1.3. Research Objectives

The purpose of this component of the research project was to quantify patterns of electrocution as they pertain to technical and biological factors. The most effective way to do this was to gather information from the utility’s records. Much more detailed information on the mechanisms of electrocution could be ascertained in this manner as compared to that which could be discovered during field surveys.

For this portion of the research, my objectives were as follows:

1) Determine the most lethal structures as reported by the utility, 2) ascertain which species are most vulnerable to electrocution within the study area, 3) quantify the discrepancy between frequency of electrocution between males and females, 4) compare

the frequency of electrocutions between age classes, and 5) describe temporal or seasonal patterns associated with raptor electrocution.

As in Chapter 2, I predicted that electrocution rates on transformer structures, deadends, and poles with lightning arrestors, cutouts or jumper wires would be higher than expected based on proportional frequency on the landscape. I predicted electrocution rates to be lower than expected on tangent structures.

I predicted that red-tailed hawks, Swainson's hawks, and great horned owls would be electrocuted most often, based upon the abundance of these species in the study area. I thought that more adults than juveniles, and more females than males would be electrocuted. Finally, I predicted that most incidents would occur between April and September, coinciding with the arrival and departure of migratory species.

3.2. Methods

3.2.1. Study Area

This portion of research was conducted within the entire 13 400km^2 study area in southeast Alberta, which includes the ATCO Electric service districts of Stettler, Forestburg and Consort. In addition, it includes the service district of Castor, which is nestled among the aforementioned three districts and is located south of Forestburg, east of Stettler, and west of Consort. These areas were chosen to compliment data collected for Chapter 2. The entire study area fell within the following span: 51°41' to 52°57'N latitude and 110°00 to 113°06' W longitude. A detailed description of the study area can be found in Chapter 2.

3.2.2. Raptor Electrocution Forms

Prior to the commencement of this research project, a substantial amount of detail was lacking in the utility's accounts of raptor electrocutions. Records noted only that a bird or “animal” caused a service interruption, the time of day, and the rough location of the fault. Fundamental details were lacking, including species and specific structures involved in raptor electrocutions. Obtaining such information was the first step in understanding the nature of the problem, so that the most effective mitigation strategies and pole design standards could follow.

A standardized raptor electrocution reporting form based on that used for the Raptor Electrocution Reduction Program (Liguori 2003) was created for the ATCO Electric service districts of Stettler, Forestburg, Consort and Castor. Designed for use when carcasses were recovered during outage investigations, the form collected information on structural characteristics including voltage of the line, presence of pole-mounted equipment and guy wires, crossarm material, and whether or not the structure had existing bird protection. Additionally, biological information regarding species involved, sex, age, injuries, and location of the carcass with respect to the pole was included. Finally, the form collected information on potential food supply within the vicinity of the pole, presence of other raptors, and any evidence of pole use such as whitewash and pellets. The Raptor Electrocution Form can be found in Appendix C.

Utility personnel officially submitted forms spanning the period from April 2003 to December 2004. Although forms were also collected from other provincial ATCO Electric districts on a voluntary participation basis, these were omitted from statistical analysis since not every district participated in this program, resulting in an inadequate representation from all parts of the province. However, forms collected from beyond the study area districts still provided valuable information and was subsequently included in the descriptive statistics.

Although Raptor Electrocution Forms were only requested for birds of prey, some districts submitted forms for other species, primarily corvids such as American crows and common ravens. Because submission of such forms lacked a systematic approach and were not within the scope of this project, they were omitted from analyses.

Utility service personnel brought the raptor carcasses to local Fish and Wildlife division offices where they were frozen. They were then taken to an Edmonton Fish and Wildlife laboratory, whereupon I confirmed species and age and noted any damage to the carcass. Finally, I dissected them to determine sex. In the event that bodies were sufficiently burnt, decomposed, or when the sex could not be determined, sex was recorded as “unknown”.

In two circumstances, two birds were electrocuted simultaneously. These were each entered as two occurrences into the database.

3.2.3. Anecdotal Evidence

During the course of this research project, a number of raptor electrocutions were reported to me through wildlife rehabilitators or members of the public. In such cases, I noted the species and age of the bird, and confirmed the category of pole by either visiting the site or obtaining photos from the finder. Because of logistical limitations, no efforts were made to determine the sex of these carcasses.

3.2.4. Statistical Analyses

3.2.4.1. Raptor Electrocution Forms

Comparisons of mortality with respect to structural configurations were subjected to Chi-Square Goodness of Fit Tests (Zar 1999, p465) to determine whether any poles electrocuted more raptors than what would be expected by chance.

All comparisons involving species, age and sex of casualties were analyzed using Log-Likelihood Ratio Tests for goodness of fit (Sokal & Rohlf 1995, pp685-708) with Williams Correction (Williams 1976), or Fisher’s Exact Tests (Zar 1999, pp543-557) when data were partitioned and smaller sample sizes ensued. Expected ratios for age classes of raptors were obtained by summarizing banding data from the Canadian

Wildlife Service (CWS) Bird Banding Office (CWS 2005). Data included that of great horned owls and red-tailed hawks banded in the study area between 1955 and 2003.

In order to be consistent with age classifications made during the dissection of carcasses, age class ratios for each species were determined using the following guidelines: for great horned owls, banding records of birds classified as AHY (after hatching year), SY (second year), ASY (after second year) and ATY (after third year) were considered adults. Juvenile birds were represented by those classified as HY (hatching year). Birds classified as L (local, or nestling birds) were omitted from age class analysis, as they do not reflect the demographic of those birds that experience electrocution, since they have not yet fledged from the nest.

During dissection of red-tailed hawks, birds that did not yet exhibit the brick-red tail characteristic of an adult were considered juveniles, thus adults were considered those classified in the banding data as ASY. Juveniles were thus represented by those classified as HY, AHY and SY. As with the great horned owl records, L category birds were not included.

In consideration of the larger sample size of the data set, the alpha value for rejecting the null hypothesis was set at 0.05. Chi-squared analyses were performed using SPSS 12.0 (SPSS Inc 2003), while Log-Likelihood Ratio analyses were done using Microsoft Excel 2000 (Microsoft Corporation 1999).

3.2.4.2. Anecdotal evidence

The anecdotal electrocutions reported to me were sporadic and were not collected in a systematic way. Additionally, because on many occasions the shock did not initially kill the bird, and as most of these events occurred close to human settlement, the shocked birds were more apt to be discovered. Considering these inherent biases, and the lack of systematic reporting, they were not subjected to statistical analyses. Nonetheless, the data still provide additional information and thus are included as descriptive statistics only.

3.3. Results

3.3.1. Raptor Electrocution Forms

Fifty-three raptors were reported electrocuted by ATCO Electric in the districts of Stettler, Forestburg, Consort, and Castor during the 21-month data collection period. Other service districts in the province reported an additional 22 raptors. All Raptor Electrocution Form data from within the study area are listed in Appendix D, Table D4.

3.3.1.1. Mortality by species

Within the study area, great horned owls and red-tailed hawks were the only species reported on the Raptor Electrocution Forms, with 35 and 18 carcasses collected, respectively.

The 22 additional electrocutions reported from other participating districts in the province included 11 great horned owls, two great gray owls (*Strix nebulosa*), one snowy owl and one Swainson’s hawk, one reported as “sparrow hawk” (presumed to be an American Kestrel (*Falco sparverius*)), and five owls and one hawk, classified only as such. One district also reported the electrocution of a great gray owl on a 72kV double deadend transmission pole.

There were two occurrences of two great horned owls electrocuted simultaneously on the same pole. The first circumstance was an adult female and juvenile of unknown sex on a single-phase deadend; the second occurrence was two adult females on a three-phase transformer structure with bushing caps (bird protection) already on the structure. The latter two birds were found with talons still interlocked.

Five great horned owls carcasses were found with prey in their talons or lying next to them. Four of these incidents occurred on transformer poles, one on a deadend.

3.3.1.2. Mortality by structure type

Significantly more raptor electrocutions occurred on three-phase transformer structures (X^2=95.491; df = 9; p<0.001) than any other structure type. Three-phase overhead to underground riser poles (herein "riser poles") were indicated as the second most common structure involved in electrocutions followed by single-phase deadends, single-phase transformers, and three-phase cutout poles. One electrocution was reported on each of the following: single-phase double deadend, single- and three-phase tangents, three-phase capacitor bank, three-phase gang switch structure, and three-phase deadend. The number of deaths associated with each structure configuration is reported in Table 3.1.

Despite an attempt to collect information on where the bird contacted the structure, this question on the form was in most cases left blank, often because it was impossible to determine this information if the outage did not cause any structural damage.

Table 3.1. Number of deaths associated with various structure types as reported on Raptor Electrocution Forms, 04/03 – 12/04. Structure categories follow classification system shown in Table 2.2.

Structure Type	No. of deaths in study area only	No. of deaths in all participating districts
3XR	25	29
3UG	8	10
1DE	7	10
1XR	5	12
3FU	2	2
3DE	1	1
1TG	1	1
3TG	1	5
1DD	1	1
3CB	1	1
3GA	1	1
1FU	0	1

The incidents of raptor electrocutions per structure configuration for each species are illustrated in Figures 3.1 and 3.2. Transformer structures alone were responsible for 57%

and 56% of great horned owl and red-tailed hawk mortality, respectively. Riser structures were the second most lethal structure to hawks, and along with single-phase deadends, were the second most dangerous poles for owls as well.

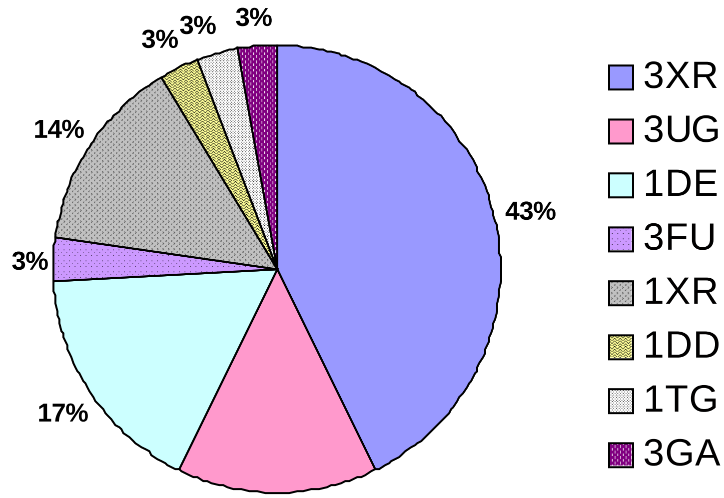

Figure 3.1. Pattern of great horned owl mortality across structure types in the study area as reported on Raptor Electrocution Forms, 04/03 – 12/04 (n = 35).

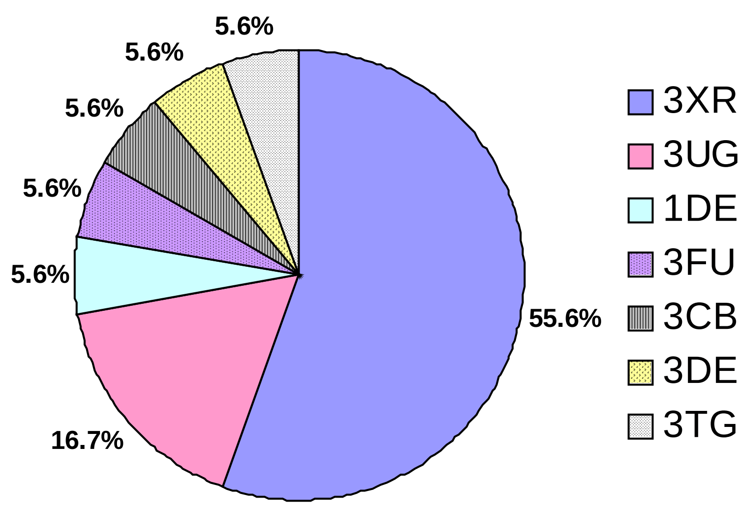

Figure 3.2. Pattern of red-tailed hawk mortality across structure types in the study area as reported on Raptor Electrocution Forms, 04/03 – 12/04 (n = 18).

3.3.1.3. Mortality by sex

Sex was determined on 23 of the 35 owls collected. Despite comprising 74% of the total, females were not electrocuted significantly more than males (G = 2.777; df = 1; p = 0.096), when the data were tested against an expected ratio of males to females of 43:57 (Table 3.2).

Within hawks for which sex was determined (n=13), 77% were females, which was statistically significant (G = 4.479; df = 1; p = 0.034) when tested against an expected male to female ratio of 52:48 (Table 3.2).

I did not receive the bodies of the 25 specimens collected from beyond the study area; consequently, they were not dissected to determine sex.

Table 3.2. Comparison of frequencies of electrocution between male and female great horned owls (GHOW) and red-tailed hawks (RTHA), as reported on Raptor Electrocution Forms, 04/03 – 12/04. Expected ratios derived from 49 yrs of banding data in the study area from the Canadian Wildlife Service Banding Office. n = total number of each species collected; p = probability of making a Type 1 error for H_0: no difference in mortality rates among sexes. Bolding indicates significance.

Species	Comparison	Expected M:F ratio	Observed M:F ratio	n	p-value
GHOW	F>M	43:57	26:74	23	0.096
RTHA	F>M	52:48	23:77	13	**0.034**

3.3.1.4. Mortality by age

Among great horned owls, age was confirmed for 32 of the 35 bodies (Figure 3.3). Adults represented 69% of the birds, but were not electrocuted significantly more than juveniles when tested against the expected annual adult to juvenile ratio of 75:25 (G = 0.625; df = 1; p = 0.429). Data were then partitioned before and after great horned owls fledge (end of May). The sample size was too small to test pre-fledging data (n=3), however the test was run on the post-fledging data (n=29). When tested against an expected adult to juvenile ratio of 52:48, no relationship was found (G = 2.108; df = 1; p = 0.147) (Table 3.3).

Among red-tailed hawks (n=18), age was confirmed for all but one bird (Figure 3.4). Adults represented 88% of the mortality and this finding was significant when compared to an expected annual adult to juvenile ratio of 52:48 (G = 10.06; df = 1; p = 0.002). However, when the Raptor Electrocution Form data were partitioned before and after the fledging period (early July), Fisher's Exact tests detected a significant relationship before (n = 9; p = 0.029), but not after (n = 8; p = 0.132) this period (Table 3.3).

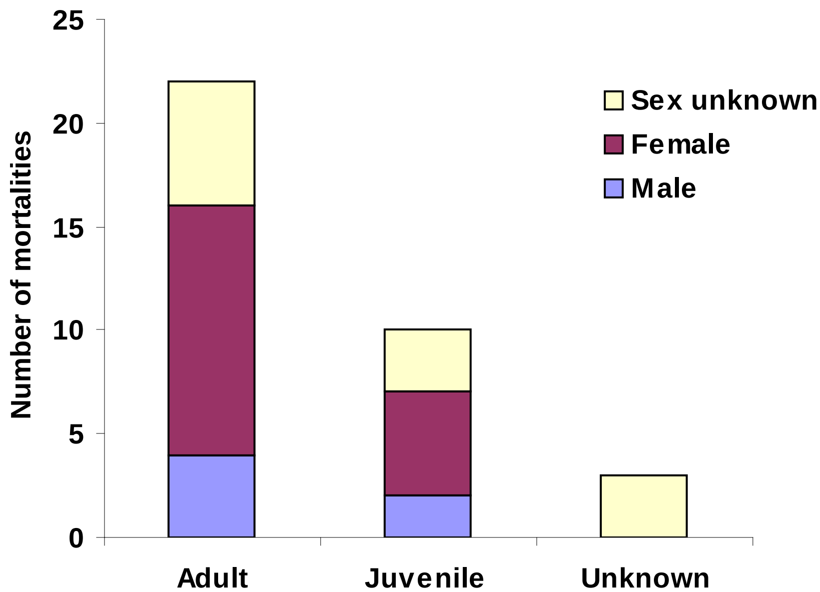

Figure 3.3. Demographic pattern of great horned owl mortality in study area as reported on Raptor Electrocution Forms, 04/03 – 12/04 (n=35).

Table 3.3. Comparison of frequencies of electrocution between adult and juvenile great horned owls (GHOW) and red-tailed hawks (RTHA), as reported on Raptor Electrocution Forms, 04/03 – 12/04. Expected ratios derived from 49 yrs of banding data in the study area from the Canadian Wildlife Service Banding Office. p = probability of making a Type 1 error for H_0: no difference in mortality rates among age classes. Bolding indicates significance.

Species	Comparison	Expected Ad: Juv ratio	Observed Ad: Juv ratio	Timeframe	n	p-value
GHOW	Ad>Juv	75:25	69:31	Annual	32	0.429
GHOW	Ad>Juv	52:48	66:34	Post-fledge	29	0.147
RTHA	Ad>Juv	52:48	88:12	Annual	17	**0.002**
RTHA	Ad>Juv	53:47	100:0	Pre-fledge	9	**0.029**
RTHA	Ad>Juv	31:69	75:25	Post-fledge	8	0.132

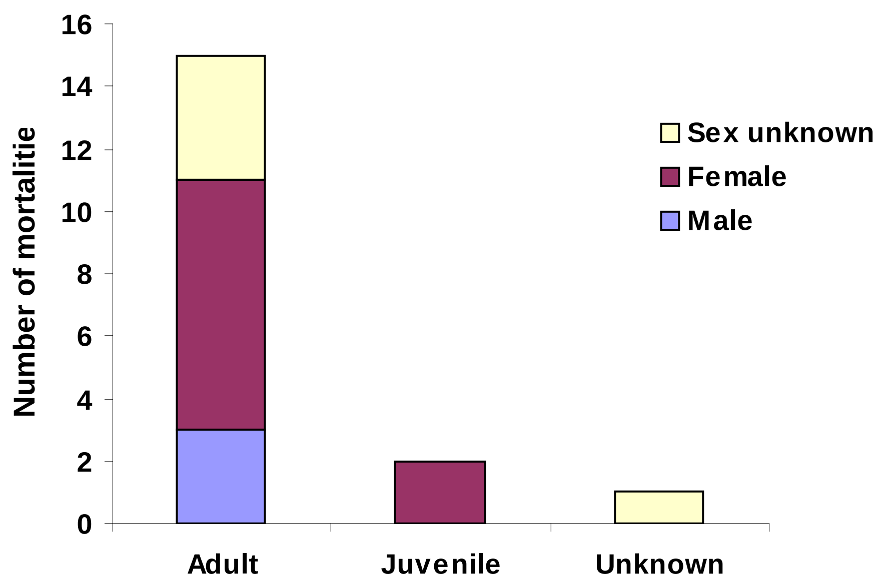

Figure 3.4. Demographic pattern of red-tailed hawk mortality in study area as reported on Raptor Electrocution Forms, 04/03 – 12/04 (n=18).

3.3.1.5. Temporal variations

No electrocutions occurred during the months of December, January and February. The majority of electrocutions (87%) occurred between April and August, peaking in July with 19 (36%) deaths (Figure 3.5). Hawk mortality was limited to the spring and summer (April – August) while great horned owls experienced electrocutions spanning the year, except for the three months listed above. Temporal patterns of electrocution beyond the study area were similar to Figure 3.5, with the exception of one owl electrocution in December 2003.

While adults were electrocuted throughout the period spanning April to November, juveniles were only reported during June, July, and August, coinciding with the fledging season (Figure 3.6).

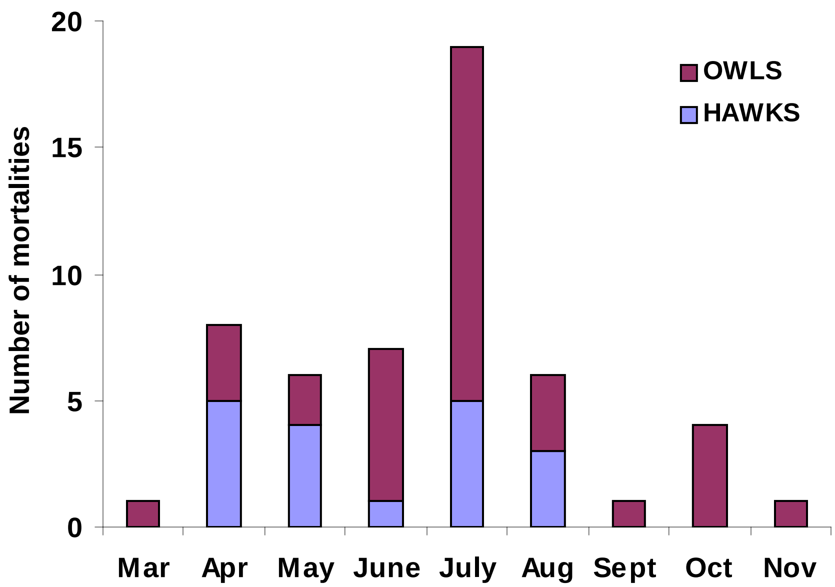

Figure 3.5. Temporal patterns of electrocution among great horned owls (n=35) and red-tailed hawks (n=18) as reported on Raptor Electrocution Forms, 04/03 – 12/04.

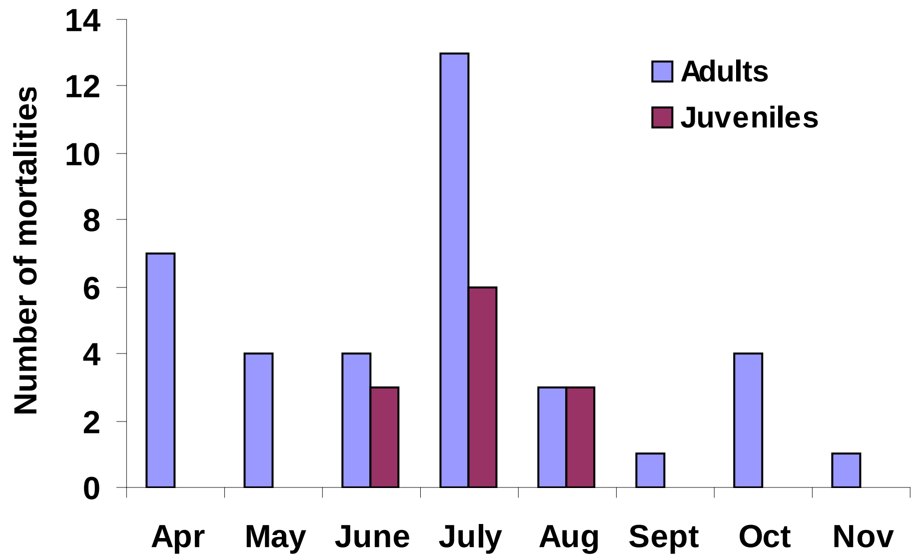

Figure 3.6. Adult and juvenile mortality (great horned owls and red-tailed hawks combined) for all birds for which age could be determined, in study area as reported on Raptor Electrocution Forms, 04/03 – 12/04 (n = 49).

3.3.2. Anecdotal Evidence

Between May 2002 and April 2005, sixteen anecdotal cases of raptor electrocution were reported to me. These included seven great horned owls, two golden eagles, two bald eagles, and two red-tailed hawks. One great horned owl that was electrocuted on a three-phase transformer pole was found with a northern flying squirrel (*Glaucomys sabrinus*) still in its talons. Species, status when found, and corresponding structures are reported in Table 3.4. Nine of the casualties were found alive, but none of these birds survived; if they were not killed during the initial shock, they either subsequently died or were euthanized at a local wildlife rehabilitator because of the severity of their injuries.

Table 3.4. Raptor electrocutions reported anecdotally 05/02 – 04/05 and associated structures as classified in Table 2.2.

Structure Category	Species[1]	Status[2]
3XR	(3) GHOW	A, D, U
3TG	(1) GHOW	D
1TG	(1) GHOW	A
1DD	(1) GHOW	A
1XR	(1) GHOW	A
1TG[3]	(4) RTHA	A, A, D, D
1DE	(1) RTHA	A
1TG[3]	(1) BAEA	A
Not reported	(1) BAEA	A
3DE	(2) GOEA[4]	D, D

[1] "GHOW": great horned owl; "RTHA": red-tailed hawk; "BAEA": bald eagle; "GOEA": golden eagle
[2] "A": Alive when discovered; "D": dead when discovered; "U": status when discovered unknown
[3] Tangent structures lacking a crossarm, with a neutral wire running parallel beneath the energized phase
[4] Both GOEA were electrocuted on separate occasions on the same structure

3.4. Discussion

The data collected by utility servicemen are difficult to evaluate because of the nonrandom technique through which carcasses were collected. Indeed, there is a bias associated with these data since they represent only the electrocution events that caused outages and were detected by utility personnel. However, if it is reasonable to assume that all birds, regardless of age class or sex, have an equal chance of causing an outage when electrocuted, then some valuable conclusions may still be drawn from this data set.

3.4.1. Lethal Structures

My predictions regarding the most lethal configurations were supported. As consistent with the literature, three-phase transformers poles were indicated as the most dangerous structure. This is explained largely by insufficient clearances between energized and grounded components on these structures. If raptors are routinely using transformers as feeding platforms or hunting perches, as opposed to the comparatively safer perch offered by wooden crossarms of other structures, then they are repeatedly exposing themselves to extremely hazardous conditions and subsequently experience higher mortality on these structures.

Similarly, riser structures proved highly dangerous to both owls and hawks, but comprised a higher proportion of mortality for the latter. Although there are numerous potential perching locations on this structure, none of them offer safety because of the number of lightning arrestors, stress cones, and jumper wires present on the pole.

As expected, tangent structures were responsible for a very small proportion of overall mortality. In one red-tailed hawk electrocution, the three-phase tangent had two insulators on one side of the crossarm, which is highly dangerous to a bird that attempts to land on that side, as the clearance between the two conductors is unusually low. ATCO Electric has long since recognized the hazard inherent in this pole design, and has omitted it from the construction standards. The second tangent structure, on which an owl was killed, was a single-phase pole lacking any guy wires, which suggests that this incident may have resulted from wet conditions. Indeed, climate records indicate that the area did accumulate 1.0cm of precipitation on the day of the incident (The Weather Network 2004).

The anecdotal evidence however, produces a different picture. In contrast to the data collected on the Raptor Electrocution Forms, tangent poles were involved in a large proportion of incidents (seven of sixteen) in which structures were identified. These data were biased in that in most cases, they occurred on or near an individual's property, and the raptors were often found alive, which might have made them more prone to detection. However, this lends strong support to the suspicion that many more raptors are electrocuted than are detected by utility companies, especially when these events do not result in an interruption to the power supply, and when they occur on structures that are generally thought to be among the safest of configurations.

3.4.2. Biological Patterns of Electrocution

3.4.2.1. Species

Only two raptor species, great horned owls and red-tailed hawks were found electrocuted in the study area. These results were not unexpected given that the former have historically been the most commonly electrocuted nocturnal raptor (Olendorff et al. 1981; Harness 1997) and red-tailed hawks were the most commonly electrocuted hawk species as discovered in an analysis of over 1400 raptor electrocution records from numerous utilities in the western United States (Harness and Wilson 2001).

The total absence of Swainson's hawk electrocutions on the utility reports within the study area was an unexpected result, as they were commonly observed in the area, and were often seen using utility structures (see Chapter 4). The slightly smaller size of Swainson's hawk as compared to the red-tailed hawk may account for this difference, but it is more apt to be a function of behavioral differences. This concept will be discussed further in Chapter 5. Moreover, rough-legged hawks migrate through the area in the early spring and late fall and have often been spotted using single-phase tangent poles adjacent to roads and highways (personal observation). This species may demonstrate a preference for these safer structures as opposed to three-phase poles in the oilfield; this is speculation and, to my knowledge, has not been documented in the literature.

No eagles were found electrocuted within the study area, which is in stark contrast to many other studies (Boeker and Nickerson 1975; Harness and Wilson 2001; Liguori 2003; Medzhidov et al. 2005). Bald and golden eagles have been observed in the study area during migration, but no cases of breeding have been confirmed according to the last published Atlas of Breeding Birds of Alberta (Semenchuk 1992). Despite this, some electrocution mortality of these large raptors might have been expected during migration.

It is difficult to draw comparisons regarding the number of reported mortalities in this study to other utilities' records, because of the diversity in size of service areas, topography within them, and other variables. Additionally, the extent to which utilities maintain records on raptor electrocutions is highly inconsistent, and these records are generally not made available to the public. Presumably, the number of mortalities reported in this study over a 21-month period is lower than in most areas. As discussed, the density of bald and golden eagles is quite low in the study area, and eagles comprise a relatively high proportion of electrocuted raptors in many other studies.

Because of the relatively cold, northerly climate in southeast Alberta, several raptor species are merely summer residents. As a result, the absolute abundance of raptorial birds decreases for almost half the year; accordingly, the number of electrocutions reported in Alberta during winter would be expected to decrease. An opposite trend may be observed in more southerly areas that support overwintering raptor populations, which naturally include a relatively high proportion of juvenile birds. Benson (1981) noted that wintering populations of eagles sometimes congregate in high densities around available food sources, and use the more energetically efficient still-hunting technique, making them more vulnerable to electrocutions.

No falcons were reported electrocuted on the Raptor Electrocution Forms during the course of this project. However, one adult female peregrine falcon was reported electrocuted on a single-phase double deadend pole in the study area in July 2005, after completion of the data collection. Falcons often constitute a relatively low percentage of electrocuted raptors, which, as Harness (1997) postulated, may be a result of their generally smaller body size which would render them less vulnerable to electrocution, or just more easily carried off by scavengers. Conversely, still-hunting may not be as valuable a technique to these avian predators, rendering utility poles less valuable to them.

3.4.2.2. Sex

This research revealed that females were electrocuted more often than males for both red-tailed hawks and great horned owls, although this was not significant for the latter. However, the banding data on owls from which expected frequencies were calculated may not be a completely accurate representation of the true sex ratio. The original data set showed a bias towards females of 36:64, based upon 243 records for which sex was determined. However, great horned owls demonstrate a sex-biased propensity to be caught by banders, especially during the breeding season: when a bander climbs to a nest to band the nestlings, the female is most often the first to return to defend the nest, thus making her more susceptible to being caught and banded (Erhard Pletz 2005, personal communication). In fact, the banding data reflected this: over half of the female great horned owls were banded during April and May, coinciding with the nesting season. These months were omitted from the data set when determining sex ratios in an attempt to remove that bias, yet females still appeared to comprise a higher proportion of the sex ratio (43:57). Indeed, a similar sex bias was also noted when Craighead & Craighead (1956) measured a male to female ratio of nestling raptors of 46:54. Thus, at the population level, females are likely more common than males. However, banding biases may still occur for both males and females throughout the year for this species and as such, the banding data may not accurately reflect the true sex ratio, thus caution should be exercised when interpreting the lack of significance of these results.

Nonetheless, the higher frequency of female electrocution of both hawks and owls primarily results from reversed sexual dimorphism. Simply put, larger birds have a higher chance of contacting two dangerous components of the structure simultaneously. In addition to the physical size distinction, behavioral differences may contribute to this as well. Dominance of large females may also lead to displacement of males from perches (Ferrer and Hiraldo 1992), leading to an increased chance of electrocution for this sex class. Intra-species competition appeared to be the cause of two adult female great horned owls that were simultaneously electrocuted during this study. Their healthy body condition, and the fact that they were found with talons interlocked, indicated a fight likely occurred that led to the demise of both individuals.

Furthermore, females of many raptor species tend to spend more time at the nest with young during the nesting period, and have a larger role in delivering food during the fledgling period (Newton 1979). If great horned owls and red-tailed hawks opt to nest on or near distribution power poles, then the comparatively high interaction time with the young and subsequent prolonged exposure to the hazard would lead to increased susceptibility to electrocution. Even if nests are situated a seemingly safe distance from utility structures, as long as the poles are within the territory, the potential for electrocution would presumably increase as adults would still be utilizing poles for hunting perches. Similarly, the young would opt to use this area while acquiring hunting and flying skills.

Since males and females are not electrocuted at an equal rate, the possibility exists that some populations may experience a sex ratio biased in favor of males. This could potentially lead to a higher incidence of immature females paired with males for breeding, as was observed by Ferrer and Hiraldo (1992). Such pairs would likely experience lower nesting success through infertility, or not laying at all (Newton 1979). This situation would likely be more prevalent in species with smaller population sizes, and would be more of a concern for sensitive species.

It was beyond the scope of this project to assess the potential impact of electrocution on raptor populations as a whole. Losing a higher number of females to this form of mortality may not have severe implications on a species such as great horned owls, especially if the adult population is naturally biased in favor of females as the banding data suggests. However, the disproportionate mortality of breeding females may have substantial impact if this pattern is consistent elsewhere among threatened species such as ferruginous hawks.

It has already been established that raptor electrocution is often the result of aggressive intra-species interactions, nesting building activity, and rearing young. If we can assume that the females involved in such activities are normally the most likely to survive to produce offspring, as evidenced by their ability to secure a mate and defend a territory, then it follows that mortality by electrocution may in fact select against the most “fit” individuals in the population. Ironically, the very characteristics that have historically ensured that a raptor would survive to contribute its genes to the next generation are the same attributes that contribute to the likelihood of its death, when this highly unnatural form of mortality is considered.

Moreover, if females are killed before the young have fledged, then such nests will have a higher probability of failure. It follows then that the loss of a breeding female during the nesting season may have a much more substantial influence on the population than it would at other times of year. Indeed, this effect may have serious consequences for threatened or endangered species, especially if acting synergistically with other factors causing population decline.

3.4.2.3. Age

My prediction regarding age distribution of mortality was supported: more adult raptors were reported electrocuted than immatures. Upon testing this finding against the expected distribution of adults and juveniles, no significant differences were found between adult and juvenile owl mortality. However, significance was detected when red-tailed hawks were examined using CWS banding data spanning both the pre-fledging period and the entire year. No relationship was found with the post-fledging data.

Despite fewer juveniles being found electrocuted than adults, the fact that all juvenile mortalities were observed during the breeding season – even for a year round resident species, the great horned owl – further supports the evidence in the literature that activities surrounding fledging and subsequent dispersal put immature raptors at high risk of electrocution during this period.

3.4.2.4. Seasonal activities

Of the 53 forms submitted from the study area districts during the data collection period, 30 and 23 forms were collected in 2003 and 2004, respectively. Although the official collection began in April of 2003, one service district submitted a form that was backdated from March of that year. This form was included in the totals but should not be interpreted as a true representation of mortality for that month as only one district backdated a form in this manner.

As anticipated, most (89%) fatalities occurred between April and September, coinciding with the arrival and departure of red-tailed hawks. This period also encompasses the fledging period of great horned owls, which often starts in May (Erhard Pletz 2005, personal communication). Not only are raptors more abundant during this period, but heightened activity surrounding the nesting season also contributes to an increased susceptibility of electrocution. Two spikes on the temporal scale are notable, in April and July. The April spike coincides with the period in which red-tailed hawks are preoccupied with territory defense, mating, and nest building, while many great horned owl nests are hatching (McInvaille and Keith 1974), resulting in increased activity surrounding hunting trips by the male.

Similarly, the spike in electrocutions in July can likely be attributed to juvenile dispersal of great horned owls, while adult red-tailed hawks are actively hunting to provide for the young, and juvenile birds are fledging from the nest. This suggestion may be supported by the fact that two great horned owls – one adult female and one juvenile - were found electrocuted at a single structure during July 2004. The adult female was carrying a prey item and may have been feeding the juvenile bird. All juvenile birds were electrocuted between June and August, when both species of raptors are learning to maneuver around the structures, and are consequently more prone to bridging the gap between energized components.

3.4.2.5. Other factors

Observations from this project lead to some indication that raptors, at least great horned owls, may be utilizing transformers as a platform for eating freshly caught prey. This speculation is based on the six great horned owls (five from Raptor Electrocution Forms and one from anecdotal evidence) that were found with whole or partial prey either in their talons or lying next to the carcass. In all but one of these incidents, the lethal pole was a transformer pole. Given that the head was missing on some of these prey items, it would appear that the owl made the kill, ate the head, and flew up to the transformer to ingest the remainder of the kill. If this is accurate, then it suggests that these birds may use transformer platforms while eating because of the added protection from potential prey robbing that this structure provides.

3.4.3. Summary

A review of this chapter's objectives and the associated findings are presented here.

1) *Determine the most lethal structures as reported by the utility.*

According to the Raptor Electrocution Forms submitted by ATCO Electric, three-phase transformer structures were responsible for significantly more electrocutions than any other structure type. Three-phase riser poles were indicated as the second most common structure involved in electrocutions followed by single-phase deadends, single-phase transformers, and three-phase cutout poles.

2) *Ascertain which species are most vulnerable to this form of mortality within the study area.*

Thirty-five great horned owls and 18 red-tailed hawks were reported electrocuted in the study area. No eagles or falcons were reported during the course of the data collection.

3) *Quantify the discrepancy between frequency of electrocution between males and females.*

In total, sex was determined for 36 of the 53 birds that were reported electrocuted. Females represented 74% and 77% of great horned owls and red-tailed hawks, respectively. The discrepancy from expected sex ratios was significant for red-tailed hawks only.

4) *Compare the frequency of electrocutions between age classes.*

Adults represented 69% and 88% of the respective great horned owl and red-tailed hawk carcasses for which age was confirmed (n=49). This difference from the expected age distribution was significant for red-tailed hawks only.

5) *Describe temporal or seasonal patterns associated with raptor electrocution.*

No electrocutions were reported between December and February. Most electrocutions (89%) occurred between April and September, coinciding with the nesting season of red-tailed hawks and great horned owls. All juveniles were electrocuted during June, July and August.

In summary, 35 great horned owls and 18 red-tailed hawks were reported electrocuted by ATCO Electric personnel during April 2003 – December 2004. It is important to stress that these birds represent events that caused an outage, a subsequent investigation, and recovery of a carcass. They do not include any electrocutions that may have occurred but that did not fulfill the above three requirements.

These data provide vital information about the structure types involved, but perhaps more importantly, biological information such as age and sex of the species involved. This information is often not acquired through field surveys unless fresh, intact carcasses are recovered.

This study revealed that adult female birds are disproportionately susceptible to this form of unnatural mortality. This could have a substantial impact on populations of threatened or endangered species, if breeding females are lost to electrocution.

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Chapter 4: Raptor utilization of power poles

4.1. Introduction

4.1.1. Preferred Poles

Not all power poles are equally attractive to raptors. The amount of use that any given pole receives depends on topographic relief, surrounding prey base, its position with respect to the prevailing wind, and the availability of natural perches (Boeker and Nickerson 1975; Miller et al. 1975; Nelson and Nelson 1976; Benson 1981). Poles that offer unique advantages and are thus used more by raptors are termed “preferred poles” (Olendorff et al. 1981).

For eagles (and presumably other raptor species as well), preferred poles are those with a crossarm mounted perpendicular to the prevailing wind, and which offer the greatest view of the surrounding landscape (Nelson and Nelson 1976). Those often include poles positioned higher on the landscape such as on hilltops or ridges, where strong thermal updrafts provide an advantage for taking off of the structure (Boeker and Nickerson 1975; Benson 1981). These structures also offer raptors the advantage of obtaining greater attack speed when hunting (Benson 1981). Typically, risk of electrocution is higher at poles that offer these advantages, as they are used most often (APLIC 1996).

Knowledge of preferred poles is very useful when utilities are prioritizing poles for retrofitting. There are two methods to determine which structures are used most readily. The first is to conduct surveys of observations of raptors on the structures; this method provides valuable information but is limited in that it only provides a snapshot in time. The second method, and arguably the most valuable in terms of information obtained, is to survey the structures themselves to check for evidence of raptor use. During field surveys, these structures can be determined by searching for high quantities of bird excrement (whitewash) on the crossarms, equipment, and beneath the pole. Other evidence includes regurgitated pellets and prey remains at the base of the pole.

4.1.2. Raptor Species in Southeast Alberta

Within the context of research on raptor electrocutions, it is imperative to know some fundamental background on the raptor species that occur in the study area. Exact population estimates were beyond the scope of this project, yet an estimate of relative abundance is useful. Those data can be compared to findings of which species are electrocuted in the area and patterns may be ascertained based upon these comparisons.

Numerous raptors inhabit the study area as either summer residents, winter residents, or while passing through during migration. Occurrence of medium and large raptor species is outlined in Table 4.1.

Table 4.1. Occurrence of medium and large raptor species within the study area: YR (year-round); S (summer); W (winter); M (migration); and breeding status within the study area: C (confirmed); PR (probable); PO (possible); N (no breeding).

Species	Occupancy[1]	Breeding[2]
Eagles		
bald eagle (*Haliaeetus leucocephalus*)	M[4]	PO
golden eagle (*Aquila chrysaetos*)	S	N
Buteo Hawks		
broad-winged hawk (*Buteo platypterus*)	M[4]	PR
ferruginous hawk (*Buteo regalis*)	S	C
red-tailed hawk (*Buteo jamaicensis*)	S	C
rough-legged hawk (*Buteo lagopus*)	M	N
Swainson's hawk (*Buteo swainsoni*)	S	C
Accipiter Hawks		
northern goshawk (*Accipiter gentilis*)	W	N
Cooper's hawk *(Accipiter cooperii*)	S	C
sharp-shinned hawk (*Accipiter striatus*)	S	C
Falcons		
gyrfalcon (*Falco rusticolus*)	W	N
peregrine falcon (*Falco peregrinus*)	M[4]	C[3]
prairie falcon (*Falco mexicanus*)	S	PO
Owls		
great horned owl (*Bubo virginianus*)	YR	C
long-eared owl (*Asio otus*)	S	PR
short-eared owl (*Asio flammeus*)	YR	PR
snowy owl (*Nyctea scandiaca*)	W	N
Other		
northern harrier (*Circus cyaneus*)	S	C
osprey (*Pandion haliaetus*)	M[4]	C
turkey vulture (*Cathartes aura*)	S	N

[1] Source: (Fisher & Acorn 1998)
[2] Source: (Semenchuk 1992)
[3] Source: (Gordon Court, personal communication)
[4] In some cases, discrepancies existed between sources

4.1.3. Research Objectives

The objectives of this portion of the research were as follows: 1) quantify the relative abundance of red-tailed hawks and Swainson's hawks in the sampling area, 2) determine whether red-tailed hawks and Swainson's hawks demonstrate preferences for perching on power poles or natural perches, 3) ascertain whether the abovementioned species prefer certain power pole configurations to others, and 4) test for a correlation between the degree of pole use and distance to the nearest natural perch.

I predicted that red-tailed hawks would be more abundant than Swainson's hawks, and that both species would prefer tangent structures over other configurations and over natural perches. I thought there would be a positive correlation between degree of pole use and the distance to the nearest natural perch.

4.2. Methods

4.2.1. Study Area

The relative abundance surveys and surveys of preferred perches were conducted within the same three sampling areas of Stettler, Forestburg, and Consort as described in detail in Chapter 2. The power pole usage data were collected throughout the entire 13 400km^2 study area, which is described in Chapter 3.

4.2.2. Relative Abundance

To quantify the relative abundance of raptors in the study area, frequency of occurrence (Dawson 1981) was measured using three-minute unlimited-distance point counts. These counts were undertaken during the electrocution evidence surveys, which began approximately 30 minutes before sunrise and were completed in the early afternoon. A pole was selected as a point count station if it was a minimum 300m from the previous count. Two observers stood back-to-back and surveyed all raptors seen with 10X42 binoculars; standing in this position allowed the observers to view the entire 360° radius surrounding the pole. Observers communicated to each other the direction any raptor was flying to avoid double counting. Data were collected on species observed, age (if possible), and activity (in flight, perched, or hunting). With the low topographic relief and extensive line-of-sight, many sightings were of distant birds that could not be determined to species. These were classified as "*Buteo*", or sometimes more generally as "raptor". Because surveys were limited to daylight hours, they excluded nocturnal raptors.

4.2.3. Power Pole Usage

In order to determine how raptors utilize power poles, data were collected any time a raptor was observed perched on a pole. Information was recorded on species, time of day, type of perching structure (pole or tree), and, if perched on a pole, where the bird was perched on the structure. These data were separated into (1) those that were collected during randomized point counts and (2) those that were collected opportunistically while traveling through the study area.

4.2.4. Preferred Poles

Each power pole surveyed during the electrocution evidence surveys was examined for signs of raptor use including whitewash on or directly below the structure, and regurgitated pellets or prey remains at the base of the pole. As poles were each surveyed twice, any pellets or prey remains found during the first visit was removed to prevent double counting. The amount of whitewash and the number of pellets found at each pole were each assigned points on a scale of 0 - 4; prey remains were assigned either 0 or 1 point. The maximum number of points that each pole could be assigned per survey was 9 (Table 4.2). Thus, the maximum number of points possible at each pole for the first and second surveys combined was 18.

Table 4.2. System of point assignment for determining degree of raptor use at each pole. Total number of points possible during each survey was 4, 1, and 4 for pellets, prey remains and whitewash, respectively. Maximum points possible per pole per survey was 9.

Points Assigned	Number of Pellets	Prey Remains	Whitewash
0	None	Absent	None
1	1-2	Present	Very little
2	3-5		Some
3	6-8		Heavy
4	>9		Very heavy

The distance to the nearest natural perch was obtained using ocular estimates. These approximations were derived using the average distance between poles for reference, which for ATCO Electric's lines is 107m and 95m on three-phase lines and single-phase lines, respectively (Brian Harris 2004, personal communication).

4.2.5. Statistical Analyses

4.2.5.1. Relative abundance

All confirmed sightings of red-tailed hawks and Swainson's hawks seen during point counts were analyzed using the Log-Likelihood Ratio Test for goodness of fit (Sokal & Rohlf 1995, pp685-708) with Williams Correction (Williams 1976).

4.2.5.2. Power pole usage

Two data sets were tested independently because they were not collected in a similar fashion. The first data set consisted of observations of birds on perch structures (trees versus poles) based on randomized point counts. The second data set was based on opportunistic sightings observed outside of point counts. For both data sets, chi-squared analysis using Yates Correction for Continuity (Zar 1999, p468) was used to test for an association between species and perch structure.

4.2.5.3. Preferred poles

Because the poles examined for evidence of raptor use were the same as those examined for electrocution evidence (see Chapter 2), the average number of use points was calculated for (1) poles without electrocution evidence, (2) poles with confirmed evidence only, and (3) poles with confirmed or unconfirmed electrocution evidence.

The test for a correlation between the degree of raptor pole use and the distance to the nearest natural perch was carried out using the Spearman's Rank Correlation procedure (Zar 1999, p395). This non-parametric test was used because data did not meet the assumptions and requirements of its parametric equivalent.

All Chi-squared analyses and Log-Likelihood Ratio Tests were performed using Microsoft Excel 2000 (Microsoft Corporation 1999). Spearman's Rank Correlation was analyzed with SPSS 12.0 (SPSS Inc. 2003).

All of the above analyses were evaluated using an alpha value of 0.05.

4.3. Results

4.3.1. Relative Abundance

All raptor species observed during point counts are shown in Table 4.3. A high proportion of birds could not be identified to species. As no harriers or eagles were reported electrocuted by the utility (see Chapter 3), the relative abundance of only red-tailed hawks and Swainson's hawks were included in the analyses. Results indicated that there was no significant difference in the abundance of these two species in the sampling areas ($G = 2.664$; $df = 1$; $p = 0.103$).

Table 4.3. Number of each raptor species seen during all point counts (n=135).

Species	Number observed
red-tailed hawk	33
Swainson's hawk	21
northern harrier	8
bald eagle	1
golden eagle	1
unknown buteo	48
unknown raptor	23

4.3.2. Power Pole Usage

During point counts, one northern harrier and one bald eagle were observed using power poles, but with such small sample sizes, they were omitted from analyses. The remainder of the data set consisted of confirmed sightings of red-tailed hawks and Swainson's hawks.

Most red-tailed hawks and Swainson's hawks were observed on the wing during point counts. Forty observations of Swainson's hawks and red-tailed hawks were made on poles and trees during point count surveys (Table 4.4). Additional perch structures included a fencepost (Krider's red-tailed hawk), a road (Swainson's hawk), and a hay bale (Swainson's hawk). Results from the point count data indicate that there is no relationship between species and perch structure (X^2=1.018; df = 1; p = 0.313). Similar results were found using the data on 154 opportunistic sightings (X^2=1.386; df = 1; p = 0.239).

Table 4.4 Number of sightings of each species utilizing poles and trees during point counts (n=40), and during opportunistic sightings (in parentheses) (n=154).

Species	Poles	Trees
Red-tailed hawk	11 (98)	10 (21)
Swainson's hawk	6 (25)	13 (10)

Observations on power poles during point counts combined with opportunistic sightings indicated a consistent trend among species; three-phase tangent poles were used more frequently than other structures by both Swainson's hawks (39%) and red-tailed hawks (60%) (Figures 4.1 and 4.2). Despite the lack of nocturnal surveys, a pair of great horned owls was also seen (opportunistically) before sunrise on two separate occasions, each perched on separate three-phase tangent structures in close proximity to each other.

Swainson's hawks spent more time on equipment structures such as deadend poles and transformers than did red-tailed hawks, and spent a larger proportion of their time on single-phase tangents (Figure 4.1). Meanwhile, red-tailed hawks were observed more often on three-phase tangents and transmission poles than Swainson's hawks (Figure 4.2). Pole use data are listed in Appendix D, Table D5.

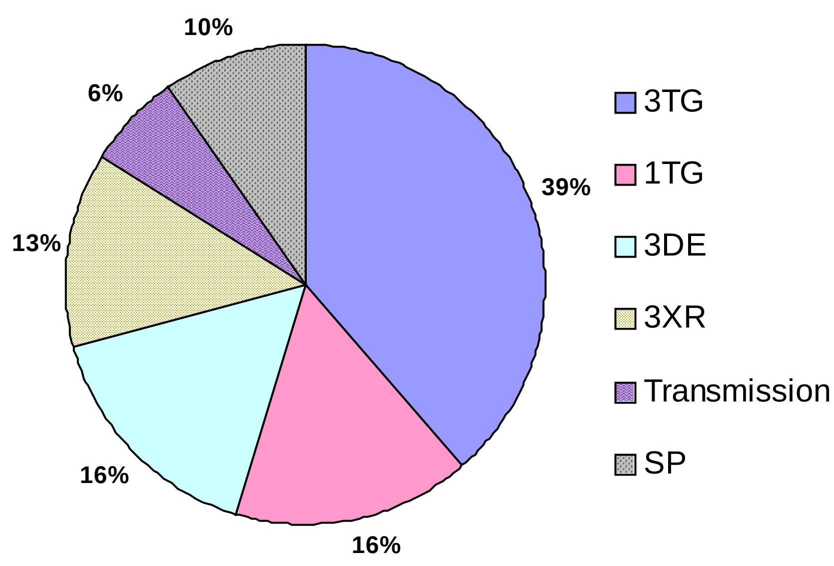

Figure 4.1. Proportion of Swainson's hawk sightings on power poles during point counts and opportunistic sightings (n=31). Categories as described in Table 2.2. Transmission poles are 72 kV tangent structures.

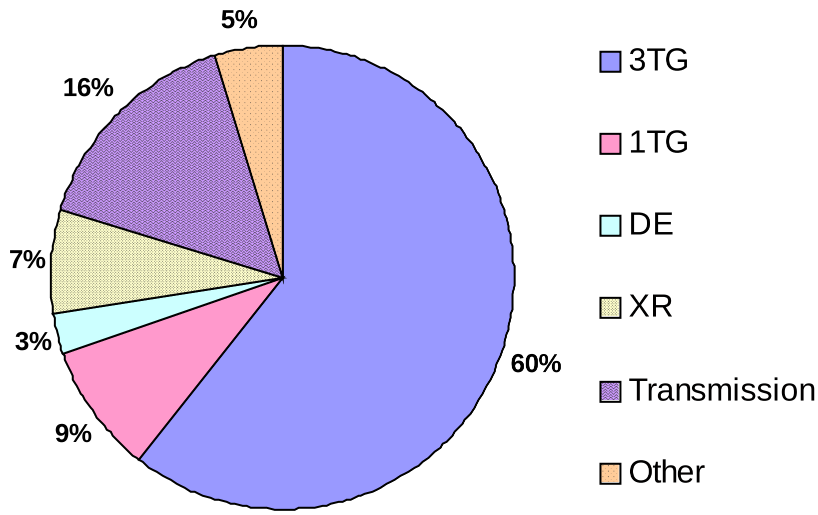

Figure 4.2. Proportion of red-tailed hawk sightings on power poles during point counts and opportunistic sightings (N=109). Categories as described in Table 2.2. Transmission poles include 72kV tangent structures and 144kV wishbone configurations; "other" includes one sighting each of 3UG and SP, and three for which the structure types were not reported.

4.3.3. Preferred Poles

Although the theoretical maximum number of points a pole could receive was 18, the maximum number observed was 9 points. The frequency of poles in each category of raptor use based on evidence from whitewash, pellets and prey remains is illustrated in Figure 4.3. Thirteen of the 16 poles in the three highest categories of use were three-phase transformer structures. When examined upon a proportional scale, more three-phase transformer structures than three-phase tangent poles demonstrated high use (Figure 4.4). However, as Figure 4.5 illustrates, the proportion of three-phase transformer poles assigned to the highest categories (categories 5 and 6) was reduced when points assigned to whitewash were eliminated.

As seen in Table 4.5, the average number of raptor use points was higher at poles that had confirmed or unconfirmed electrocution evidence than those without, when all raptor use evidence was considered as well as when whitewash was excluded. Conversely, poles with just confirmed electrocution evidence had a higher average of points than poles without electrocutions only when points assigned to whitewash were eliminated from the scoring system (Table 4.5). The total number of points assigned to each pole, both including whitewash and excluding whitewash, are found in Appendix D, Table D1.

Distance from the pole to the nearest natural perch ranged from 7.5m – >1km, with a median of 200m. There was a very weak positive correlation between the degree of pole use and the distance to the nearest natural perch ($r_s = 0.116$; $p = 0.024$).

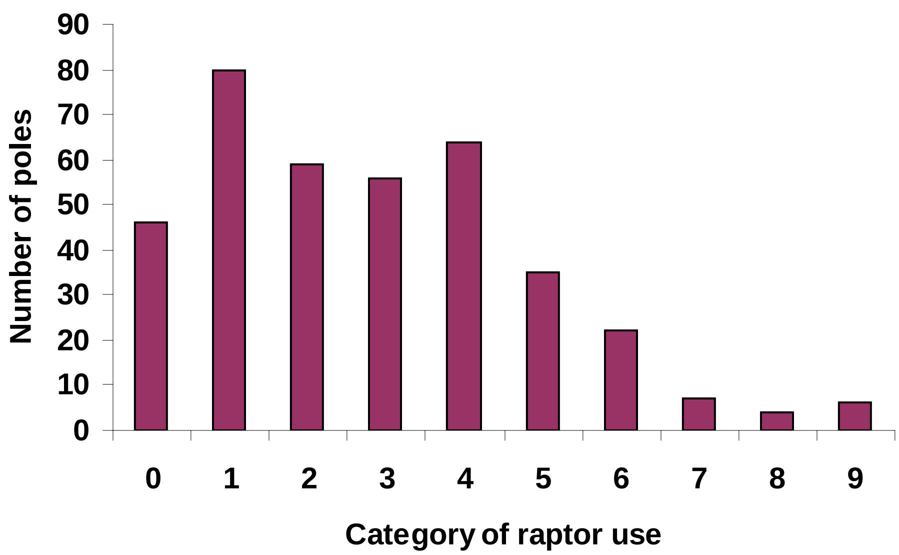

Figure 4.3. Number of poles within each category of raptor use; 0 = no use; 9 = high use (n=379).

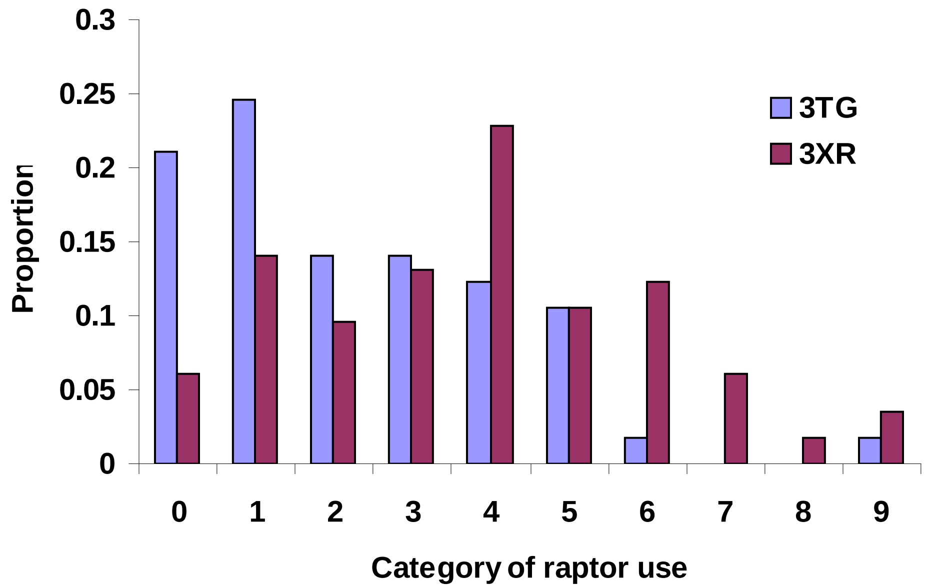

Figure 4.4. Proportion of 3TG (n=57) and 3XR (n=114) poles sampled that were classified to each category of raptor use based on whitewash, pellets and prey remains. 0 = no use; 9 = high use.

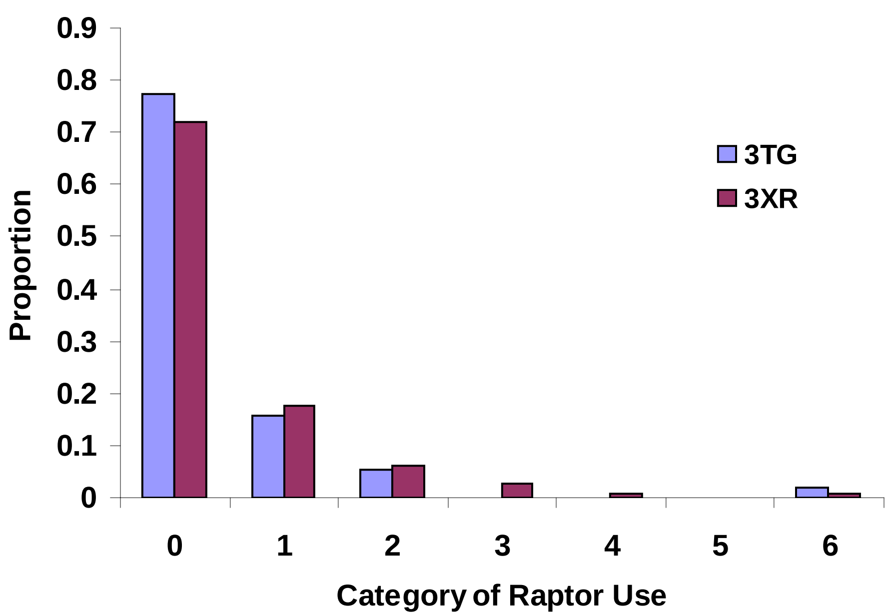

Figure 4.5. Proportion of 3TG (n=57) and 3XR (n=114) poles sampled that were classified to each category of raptor use based on pellets and prey remains only. The number of categories were reduced when points from whitewash were eliminated. 0 = no use; 6 = high use.

Table 4.5. Comparison of the average number of raptor use points assigned to poles with no electrocution evidence compared to those with confirmed evidence only and those with confirmed or unconfirmed evidence. Total points are shown including those measuring all types of evidence (whitewash (WW), pellets (P) and prey remains (PR)) and those measuring pellets and prey remains only (n=379 total poles; n=6 confirmed poles; n=20 confirmed and unconfirmed poles combined).

Pole classification	Avg total points (WW, P, & PR)	Avg total points (P & PR only)
Poles without evidence	2.79	0.32
Confirmed poles	2.17	0.50
Confirmed & Unconfirmed poles	3.15	0.65

4.4. Discussion

4.4.1. Relative Abundance

Patterns of resource use of red-tailed and Swainson's hawks are very similar, resulting in direct competition (Janes 1994). Given the open-country habitat of the study area, it was not surprising that both species were relatively common. Although more red-tailed hawks than Swainson's hawks were observed during the point counts, no statistically significant difference was detected in abundance. This result is interesting in light of the stark contrast in number of each species that were reported electrocuted (Chapter 3); this phenomenon will be discussed further in Chapter 5. Over half of the raptor sightings during the counts were not identified to species; consequently, these results are based on a relatively small proportion of actual raptor sightings.

4.4.2. Power Pole Usage

This study revealed that there appears to be no preference for perching on poles or trees by either red-tailed hawks or Swainson's hawks in this area. This is surprising given the number of red-tailed hawks that were reported electrocuted in utility reports (Chapter 3). However, the analysis was run based on the assumption that although it is easier to spot a raptor on a power pole than in a cluster of trees, that this bias is equal between species because of their similar size and coloration. In other words, there would be an equal chance of not detecting each species if an individual was perched in trees. However, if one of those species truly had a strong preference for trees, this may lead to incorrect conclusions regarding preference. Suppose we assumed, for example, a 20% probability of not detecting each species when they are perched in trees. If red-tailed hawks divided their time equally between poles and trees, while Swainson's hawks chose trees over poles 80% of the time, we would miss more sightings of the latter in trees, thus leading to incorrect conclusions not only about the perch preferences, but relative abundance as well.

Given that Swainson's hawks are, in general, more of an open-country hawk than red-tailed hawks, a more likely explanation is that there may be a third perching structure, such as fence posts or hay bales, that Swainson's hawks prefer over poles, but were not examined in this study. If this was to be measured in the future, then results might then indicate a preference for poles by red-tailed hawks, compared to Swainson's hawks. This hypothesis may be supported by the comparatively large number of red-tailed hawks observed during opportunistic sightings, which were most often spotted atop power structures. Indeed, Janes (1994) found that red-tailed hawks preferred territories with a higher density of perches as compared to Swainson's hawks, indicating that the former may rely more heavily on utility structures.

Results from combining sightings of raptors on utility structures from both point counts and opportunistic observations show that both red-tailed and Swainson's hawks use three-phase tangent structures most often. This is what would be expected given the disproportionate representation these structures occupy on the landscape (see Chapter 2). From a conservation standpoint, this situation is ideal considering the relatively low proportion of mortality for which three-phase tangents are responsible. All else being equal, these structures would logically be the most attractive to raptors while hunting, as they offer the most unobstructed landing platform and view of the surroundings. The transmission structures that comprised the majority of the sightings on which red-tailed hawks were seen were 72kV tangent structures, which are of a similar configuration to the three-phase tangents, but larger.

4.4.3. Preferred Poles

Most poles demonstrated little or no evidence of raptor use. When all types of evidence (whitewash, pellets and prey remains) were considered, sixteen poles were classified as high-use (Figure 4.3), thirteen of which were three-phase transformer structures. Similarly, when examined from the standpoint of proportion of poles of each category sampled, more three-phase transformer poles than three-phase tangents are classified as high-use (Figure 4.4) which suggests a preference for the former.

These results appear opposite to the apparent preference for tangents noted during point counts and opportunistic sightings. This discrepancy can likely be attributed to the amount of equipment and number of crossarms that three-phase transformer structures support compared to three-phase tangents. Simply put, there is more area onto which whitewash can fall, thus making it more apt to be classified as a high-use pole. This becomes apparent when the proportions of the same two pole categories are compared again, excluding whitewash evidence: indeed, proportionately more tangents are classified as high use than transformers (Figure 4.5). Assessing pole use in the absence of whitewash is likely more accurate than including it, as the amount of precipitation an area has recently experienced can strongly influence how much whitewash is detected at any given time.

In order to determine whether or not poles involved in confirmed or possible electrocutions received more use than poles without electrocutions, two comparisons were made between the average number of points between these groups, one comparison including whitewash and one excluding whitewash. In all cases except when confirmed evidence poles were examined using whitewash as evidence, structures involved in confirmed or possible electrocutions received more use than those that had no evidence of electrocutions (Table 4.5). This seems to support the theory that raptors are electrocuted more frequently on preferred poles. The abovementioned anomaly was likely a function of the small sample size of confirmed poles and the disproportionately high amount of whitewash that can accumulate on equipment structures compared to tangent poles.

A very weak significant correlation was detected between the amount of evidence of use associated with a pole and the distance to nearest natural perch. This indicates that while the hypothesis of a positive correlation between the two variables is better than the null hypothesis, much of the variation observed remains unexplained. This result can be attributed to the design of this study. Because this question was not an original objective of this project, it was not designed in a manner to best answer it. As a result, while there was often much variation regarding preferred poles within a very localized area (for example, a section), the distance to the nearest natural perch was consistent within the immediate area. In other words, at a very localized scale, variability in preferred poles likely were more influenced by structural configurations and height advantages offered by the poles themselves, than the environmental factor examined.

4.4.4. Summary

A review of this chapter's objectives and the associated findings are presented here.

1) *Quantify the relative abundance of red-tailed hawks and Swainson's hawks in the sampling area.*

Although more red-tailed hawks than Swainson's hawks were observed in the study area, this difference in abundance was not significant. Too few other species were sighted for statistical comparison of relative abundance.

2) *Determine whether red-tailed hawks and Swainson's hawks demonstrate preferences for perching on power poles or natural perches.*

No preferences were detected for perching structure by either *Buteo* species.

3) *Ascertain whether the abovementioned species prefer certain power pole configurations to others.*

Sightings in the field indicated that both red-tailed hawks and Swainson's hawks preferred three-phase tangents to equipment structures. While evidence of raptors' use of the poles initially suggested the opposite, a higher proportion of tangent poles were classified as high-use when points assigned to whitewash were eliminated from the comparison.

4) *Test for a correlation between the degree of pole use and distance to the nearest natural perch.*

A very weak positive correlation was detected between the distance to the nearest natural perch and the amount of evidence of raptor use at poles. The robustness of this result is questionable, as surveys were not designed to focus on this objective.

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Chapter 5: General discussion and management recommendations

5.1. Species and Demographic Patterns of Electrocution

On an evolutionary timescale, mortality of raptors by electrocution on power lines is a very new threat. Its effects have been documented on countless species around the globe, and it is the primary threat to some endangered species. Despite having been the subject of extensive research, this problem still exists and is not expected to diminish as less-developed nations become industrialized (Bevanger 1994).

After correcting for the effects of scavengers, this research suggests that an estimated 1.01 – 4.26 and 0.02 – 0.23 raptors are lost to electrocution per oilfield and rural section, respectively, in the study area. This figure extrapolates to 542 - 2762 raptors across the entire 13 400km^2 study area during this period. To put this into perspective, this is an average loss of 3.77 – 19.22 raptors per township and 0.11-0.53 raptors per section, during a six-week period in the summer season.

The two species that were reported electrocuted in the study area between April 2003 and December 2004, great horned owl and red-tailed hawk, were also the two most common non-eagle species reported electrocuted in the literature. In contrast to most research, however, no eagles were reported killed in the study area on the Raptor Electrocution Forms. This can be attributed to the presence of very few resident eagles. No ferruginous hawks, peregrine falcons, or prairie falcons were found or reported electrocuted during the course of this project. Although none were observed during the fieldwork, all three species have been known to occur, and even breed, in the study area (Chapter 4, Table 4.1). The absence of electrocutions of these species may be attributed to the short timeframe of the study and naturally low occurrence of these raptors. Indeed, the literature has reported electrocutions of these three species elsewhere (Benson 1981; Harness 1997; Kruger 2000; Liguori 2003), and one peregrine falcon was reported electrocuted in the study area after the completion of the data collection. Additionally, falconers within Alberta have been known to lose peregrine and prairie falcons to electrocution when flying under falconry conditions, especially in wet weather (Alastair Franke 2005, personal communication).

Although difficult to compare to most electrocution studies, the data derived through Raptor Electrocution Forms indicate electrocution rates lower than those reported elsewhere. This can be attributed primarily to the lack of many year-round resident species in Alberta.

Given that there was no statistically detectable difference in relative abundance of red-tailed hawks and Swainson's hawks, it was surprising that none of the latter were reported electrocuted within the study area, and only one report from elsewhere in the province. Considering that the size range of these birds overlap substantially, it is unlikely that this phenomenon is the result of physical attributes. The mechanism driving this discrepancy may be behavioral differences inherent in the two species that were not documented by this research project. Although this study did not find any preferences for perching structure between the two species, perhaps there was a third perching structure that Swainson's hawks do prefer but was not sampled. One study found that red-tailed hawks more easily relinquished territories with lower perch densities to Swainson's hawks, and fiercely defended areas with high perch densities (Janes 1994), indicating that the former may rely more heavily on utility poles than the latter. Janes (1994) also indicated that red-tailed hawks rely more heavily on elevated perches for hunting, while Swainson's hawks are more prone to hunt on the wing. The latter may be more agile while hunting, as they have higher aspect ratio and lower wing loading compared to red-tailed hawks (Janes 1994), which would presumably offer an aerial advantage. Harness (1997) also reported many fewer Swainson's hawks than red-tailed hawks electrocuted when compiling data from 58 utilities in the western United States. However, the relative abundance of each species was not measured.

From a demographic perspective, adult female raptors in the study area appear most vulnerable to electrocution. This is consistent with other studies that have examined this issue on summering raptor species. This phenomenon may have considerable impact on populations, as it tends to eliminate the largest and possibly the healthiest birds in the population; the magnitude of this effect is likely to be much greater on threatened or endangered species. Within Alberta, this may be of specific concern with respect to ferruginous hawks, peregrine falcons and prairie falcons.

5.2. Lethal Structures

From both fieldwork and utility reports, three-phase transformer structures were indicated as the most lethal to raptors. These poles have been repeatedly identified in the literature as the most hazardous configuration. The fact that some raptors (particularly owls) have been killed on these poles in association with a prey item suggests that they use large, flat, transformer boxes as feeding platforms. This is somewhat surprising, given the complexity of equipment on the structure; the way most transformer poles are designed, a bird can only approach it from three sides, as the pole blocks the fourth direction. It would seem logical that a raptor should prefer to feed on a platform that (1) is easier to alight and take off from and (2) provides wooden footing rather than the more slippery metal. The fact that raptors still opt for these poles suggests that there may be another, less obvious factor that attracts them. Perhaps the pole on one side of the transformer offers a sense of security from potential prey thieves. Alternatively, the transformer may provide warmth that other poles do not, which would be beneficial in the winter. The third potential explanation is that the electromagnetic field surrounding the transformer is attractive to birds. Clearly, further research is warranted in this area.

Other equipment structures such as riser structures, single-phase transformers, deadend poles and cutout structures were also responsible for a substantial portion of mortality. Three-phase tangents were least likely to pose a threat to owls and hawks when compared to the relative occurrence of these structures on the landscape. Single-phase tangents also appeared relatively safe through the Raptor Electrocution Forms and through fieldwork; however, these poles were not sampled heavily during field surveys because they were seldom encountered in oilfields where the work was conducted. Conversely, they were identified as the single most dangerous structure though anecdotal evidence, providing support to the hypothesis that there may be a considerable discrepancy between events that cause outages and the true number of electrocutions that occur. When a raptor is electrocuted on a tangent structure, it may in some cases be blown right off the pole, and not caught up on pole-mounted equipment, thus making it easier for the line to reset itself and not result in an outage and subsequent investigation (Harness 1997). Finally, three-phase gang structures were not incorporated into the total mortality estimates, as they were not encountered during the power pole inventory. Despite their relatively low occurrence on the landscape, they are sometimes involved in electrocution incidents, as evidenced by the one report submitted by the utility (Chapter 3).

Clearly there is a large discrepancy between the number of electrocutions reported by the utility and the estimates obtained from field surveys. However, the latter estimate incorporates all mortalities that did not cause a power outage and thus would not have warranted an investigation, and those for which an investigation took place but a carcass was not detected. Because of the uncertainty inherent in the unconfirmed remains that formulate the upper range of the estimate, the lower end of this range is likely a more accurate reflection of true mortality as it incorporated only confirmed electrocutions. Additionally, extrapolating the results to a much larger area than that which was sampled may have decreased the accuracy of the estimate, because this extrapolation assumes that all variables, including raptor density, scavenging pressure, and prey abundance, remain constant. Regardless of the size of the discrepancy, it is clear that electrocution causes considerably more deaths than are detected by electric utilities.

The scavenging results suggest that surveys seeking electrocution evidence should be conducted at much shorter time intervals than was logistically possible in this study. Even after seven days, scavengers had removed almost half of the carcasses; accordingly, it is imperative that scavenging pressure be taken into account by any research that conducts similar surveys.

5.3. Positive and Negative Effects of Power Poles

Indeed, power poles represent a tangible source of mortality for certain raptor species. Yet these same power poles serve a variety of other functions as they offer much-needed hunting perches and nesting platforms. This then presents the question: do power poles have a net positive or a net negative effect on raptors? This question cannot be answered in its entirety based on this research, but a discussion seems warranted.

Utility structures have undoubtedly opened up habitat that was once unavailable for open-country raptor species. Human settlement in native prairies and subsequent cultivation of the land has led to changes in the diversity, composition, and abundance of prey such as ground squirrels (Zelenak and Rotella 1997; Kaufman et al. 2000), other rodents (Kirsch 1997; Kaufman et al. 2000) and lagomorphs (Zimmerman et al. 1996). Anthropogenic alteration of the land intensified as human density increased, and large-scale farms and oil and gas extraction necessitated a network of roads and subsequent power lines that typically follow the same right-of-way. As roads fragmented the landscape, edge effects ensued, such as the introduction of non-native grasses in the roadside ditches (Zimmerman et al. 1996; Kirsch 1997; Kaufman et al. 2000). The comparatively dense vegetation present in roadside ditches provides excellent cover for small mammals. Therefore, compared to adjacent agricultural fields, roadside ditches offer a higher diversity and abundance of prey (Kirsch 1997), resulting in superior hunting opportunities for raptors (Zimmerman et al. 1996). Thus, utility structures provide an opportunity for raptors to exploit a food resource that would be otherwise largely unavailable to predators that prefer the sit-and-wait hunting technique.

Whether or not power poles produce a net positive or net negative effect on raptors cannot be stated unequivocally. The net effect depends on whether the presence of utility structures has actually increased the population of breeding pairs of any given species. In cases where electrocution has been cited as one of the primary causes of mortality for a species, the increase in breeding pairs, if indeed there is one, may not offset losses from electrocution. For species that are threatened or endangered by extrinsic factors, mortality by electrocution may inevitably compound the problem by removing breeding females that are crucial to maintaining the genetic diversity and structure of the population in the long-term.

For raptors for which the net effect is unknown, it is more appropriate from a raptor conservation standpoint to exercise the precautionary principle, and minimize this source of mortality as much as possible. The following section describes suggested methods for accomplishing this.

5.4. Management Recommendations

The ideal situation when trying to minimize raptor electrocutions on power lines is to incorporate raptor protection into the design of each structure. Although the United States Bureau of Land Management incorporates requirements for raptor protection into its operations manual (APLIC 1996), this is not the case in Canada. Currently, the Canadian Electrical Code, which is mandated by the Canadian Standards Association, does not include guidelines for raptor protection (Garth Ryland 2005, personal communication).

Nonetheless, many electric companies have incorporated such considerations into current construction standards. While this is the most effective solution in the long-term, it only serves to protect raptors on future poles. Given the prolonged lifespan of power poles, retrofitting existing structures is crucial to providing safety to raptors in the interim.

The Avian Power Line Interaction Committee recommends maintaining 60 inches (152.4cm) of clearance between energized phases (APLIC 1996). This guideline was set based on wrist-to-wrist measurements of golden eagles. However, because this research project did not identify eagles to be at high risk of electrocution in the study area, the focus of the following recommendations are primarily to protect hawks and owls.

Published wrist-to-wrist measurements of red-tailed hawks and great horned owls were not found, however I had the opportunity to measure three great horned owls that were admitted to a local wildlife rehabilitator. The largest of the three was an adult female with a wingspan of 132cm, and a wrist-to-wrist measurement of 53.5cm. This likely is not representative of the largest of this species, as Fisher and Acorn (1998) report wingspans up to 152cm, substantially larger than what I measured. Additionally, Rick Harness (2005, personal communication) provided an 81.3cm wrist-to-wrist measurement of a red-tailed hawk that had a wingspan of 137cm, which was measured by Carin Avila of the Rocky Mountain Raptor Program. Again, because this species can have wingspans up to 147cm (Fisher and Acorn 1998), this measurement is likely not representative of the largest birds. Based on the above measurements, a conservative estimate of a safe clearance for these species is 90cm (35.5 inches).

Ideally, standards should be maintained to protect eagles as well. However, given the absence of electrocution of these birds in the study area and the frequent mortality of hawks and owls, priority should be to address those structures associated with these deaths before retrofitting, for example, three-phase tangent structures, which are more dangerous to eagles but relatively safe to hawks and owls. Fortunately, most of the recommendations below will still meet the 60-inch requirement, and will protect eagles as well. However, if the recommendations are to be implemented beyond the study area, population surveys of eagles are necessary prior to any pole modifications to determine the appropriate minimum clearances.

In this section, without referencing the cost of retrofitting particular structures, I will outline considerations and recommendations for making utility structures safer for raptors. First, I will list coarse-scale priorities that do not apply to specific power poles in general, but that should be incorporated into management plans. Second, I will outline general rules applicable to any structures that contain the features mentioned. Last, I will present the fine-scale prioritization system for retrofitting individual structure designs that should be used in within the coarse-scale framework. All items within the coarse- and fine-scale prioritization systems are listed in order of highest priority to lowest. With the exception of the item denoted by (*), all course-scale priorities and general rules are based on suggestions by APLIC (1996) and Harness (2000; 2005). Although these recommendations are consistent with the findings of this study, they were not explicitly formulated as a consequence of this project.

Coarse Scale Priorities

1. Structures known to have electrocuted raptors in the past.
2. Structures that are known or suspected preferred poles.
3. Structures located within 1km of a known raptor nest.

General rules for all power structures with wood poles with wood crossarms (in no particular order)

1. Provide 90cm separation in great horned owl and red-tailed hawk habitat*.
2. Provide 152.4cm (60”) separation in eagle habitat.
3. If the above clearances cannot be provided in the respective habitats, isolate or insulate the primary configuration.
4. Install bushing covers on equipment (transformers, regulators, capacitors, and reclosers).
5. Cover exposed jumpers wires (preferred) or insulate with weatherproof copper wiring.
6. Install insulating caps on lightning arrestors.
7. Insulate or isolate cutouts.
8. To reduce phase-to-ground contacts, all guy wires that extend near conductors should be fitted with a guy strain insulator or the conductors should be insulated.
9. Metal crossarm support braces should be replaced by wood.

Specific Context Prioritization System

1. **Transformer Structures (3XR, 1XR):** Apply bushing caps and insulate all jumper wires; apply cutout covers; insulate all lightning arrestors
2. **Three-phase overhead to underground riser structures (3UG):** insulate stress cones with caps; insulate all jumper wires; apply cutout covers; insulate all lightning arrestors
3. **Single-phase deadend structures (1DE, 1DD):** add a non-conductive extension link; insulate jumper wires
4. **Three-phase deadend structures (3DE, 3DD, 3DEM):**
   - **a.** *Where there are horizontal insulators only:* insulate all jumper wires; add a non-conductive extension link or a deadend conductor cover to the central conductor
   - **b.** *Where pin-type insulators connect to horizontal insulators:* reroute jumper wires on outer conductors beneath crossarm; insulate all jumper wires; add a non-conductive extension link to central conductor or a deadend conductor cover
5. **Three-phase cutout structures (3FU):** insulate jumper wires between cutouts and conductors above; apply cutout covers
6. **Three-phase tangent structures (3TG):**
   - a. *Standard configuration (if bird previously electrocuted at structure):* apply a conductor cover to center insulator or suspend outer insulators below the crossarm
   - b. *With two insulators on one side of the crossarm:* apply a conductor cover to the insulator closest to the pole; a perch deterrent can also be used to shift the bird to the opposite side of the crossarm
7. **Three-phase capacitor banks (3CB):** apply caps to all bushings; insulate all jumper wires; insulate all lightning arrestors
8. **Three-phase gang switches (3GA):** insulate all jumper wires; install an elevated perch above any problem switches

This prioritization system is based upon structures that were identified in raptor electrocution events during this research project. It is important to note that other potentially dangerous structures exist that should be retrofitted as necessary based on the principles inherent in the above recommendations. Furthermore, although I did not include specific guidelines for future designs, they should incorporate the above recommendations to eventually phase out the necessity of pole modification. Based on the structure inventory and data collected on the Raptor Electrocution Forms, I estimate that if all but the tangent poles are retrofitted in the order listed above, that 96% of electrocutions could eventually be eliminated by retrofitting 32% of poles.

In addition to the abovementioned recommendations for retrofitting individual poles, key raptor breeding areas should be identified and avoided when planning power line routes in order to reduce the potential for electrocution in the future.

5.5. Future Research

While this research has identified some of the fundamental mechanisms behind raptor electrocution in Alberta, more research needs to be conducted in this area and elsewhere. First, a comparative before and after field test of the efficacy of the above retrofitting options is necessary. As seen by the evidence of electrocution collected beneath structures that have been modified for raptor safety, mitigation measures are not always successful, at least in the long-term; ongoing monitoring is necessary to replace ineffective, degraded or weathered pole modifications. Adaptive management should be continued indefinitely, as more research and new solutions and products become available. Second, behavioral studies should address the mechanisms behind the attraction of raptors to transformer structures so that a solution can be developed to discourage raptors from using these structures entirely. Third, it would be valuable to have a cost-benefit analysis conducted to compare the costs of placing new lines underground as compared to the those incurred by above-ground construction plus costs incurred by avian related power interruptions.

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Appendix A. Photos of poles as categorized in Table 2.2. Photos were not available for 1CR and 3GA.

Figure A1. Single-phase transformer pole (1XR).

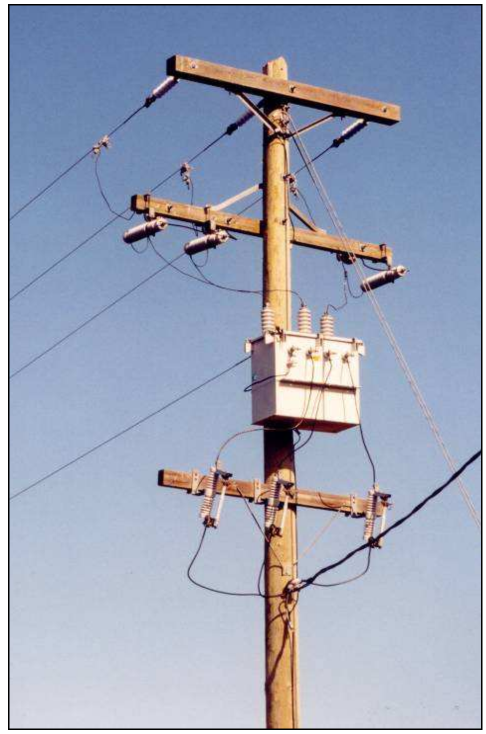


Figure A2. Three-phase transformer pole (3XR).

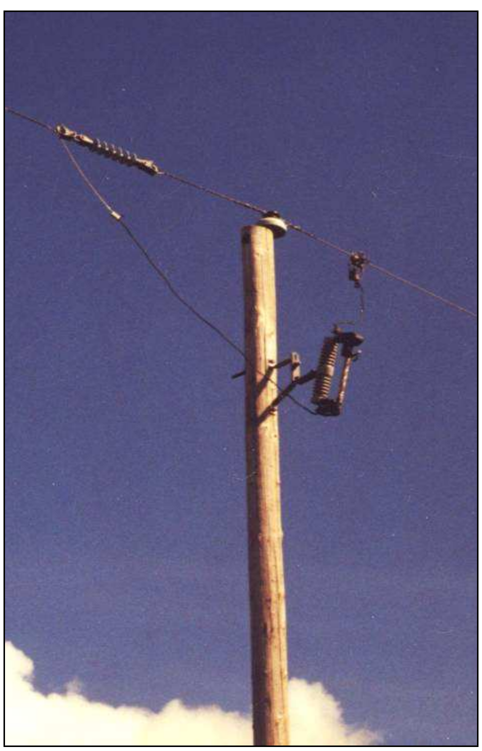


Figure A3. Single-phase cutout pole (1FU).

Appendix A (con't). Photos of poles as categorized in Table 2.2.

Figure A4. Three-phase cutout pole (3FU).

Figure A5. Single-phase deadend pole (1DE) (in this case, overlain by a three-phase tangent pole).

Appendix A (con't). Photos of poles as categorized in Table 2.2.

Figure A6. Three-phase deadend pole (3DE).

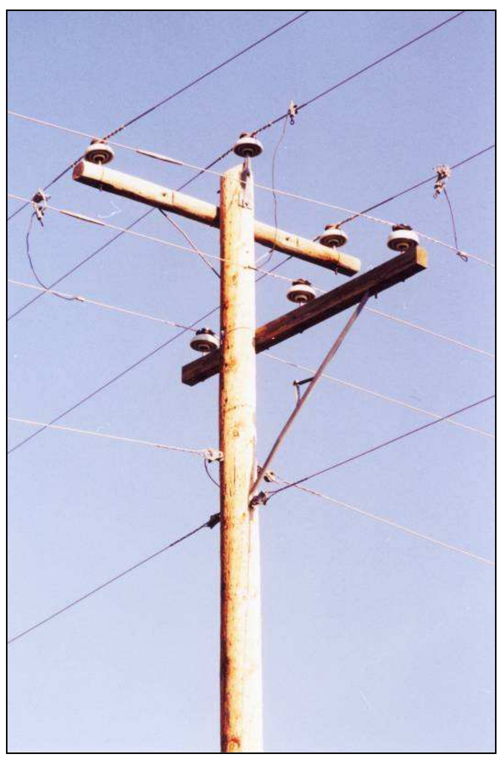


Figure A7. Three-phase corner pole (3CR).

Appendix A (con't). Photos of poles as categorized in Table 2.2.

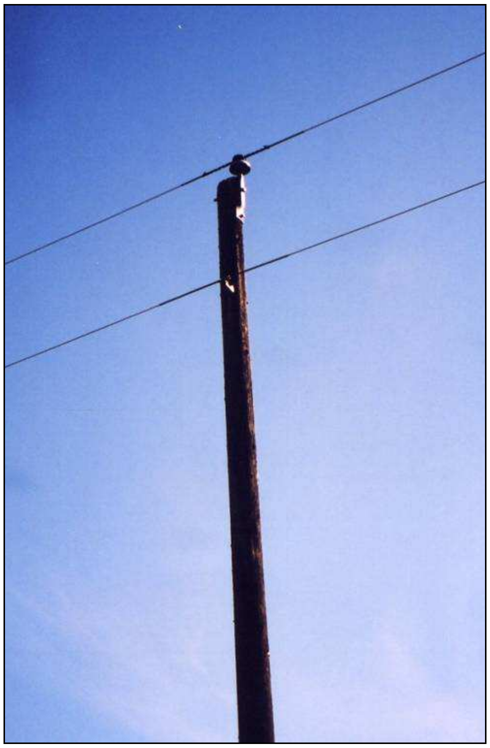


Figure A8. Single-phase tangent pole (1TG).

Figure A9. Three-phase tangent pole (3TG).

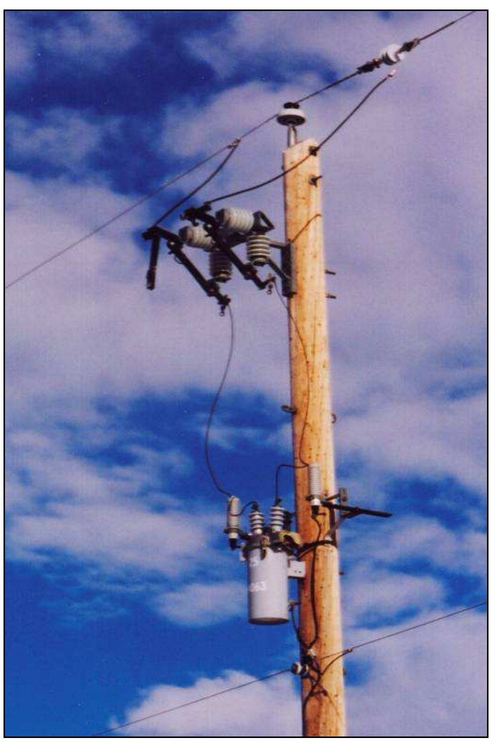


Figure A10. Single-phase recloser pole (1RC).

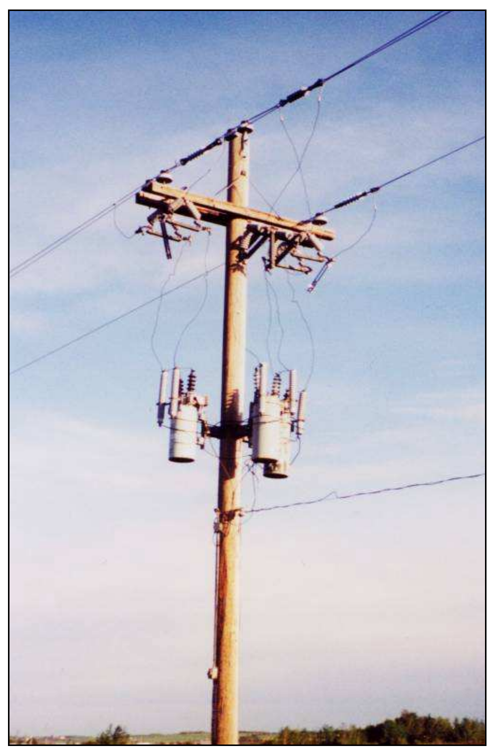


Figure A11. Three-phase recloser pole (3RC).

Appendix A (con't). Photos of poles as categorized in Table 2.2.

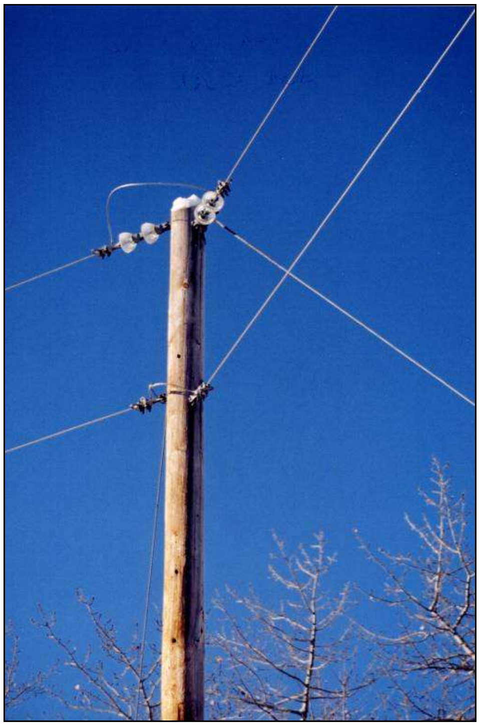


Figure A12. Single-phase double deadend pole (1DD); this pole has been modified by the utility by looping the jumper wire to the side instead of over the pole top, after a red-tailed hawk had been electrocuted on the structure.

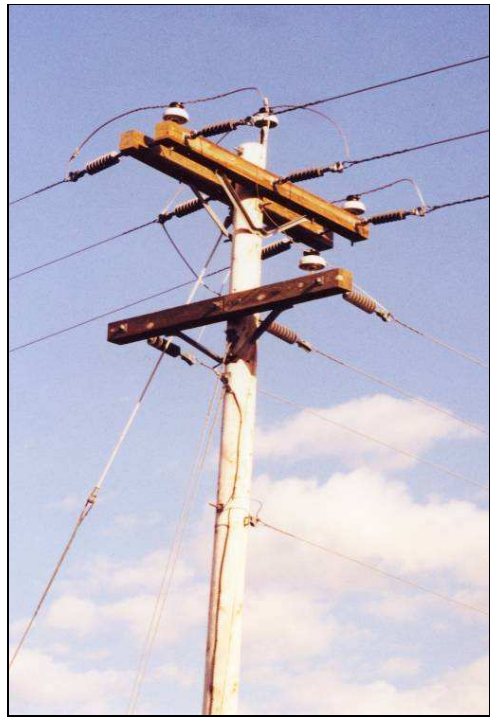


Figure A13. Three-phase double deadend pole (3DD).

Figure A14. Three-phase modified deadend (3DEM).

Appendix A (con't). Photos of poles as categorized in Table 2.2.

Figure A15. Single-phase regulator bank (1RB).

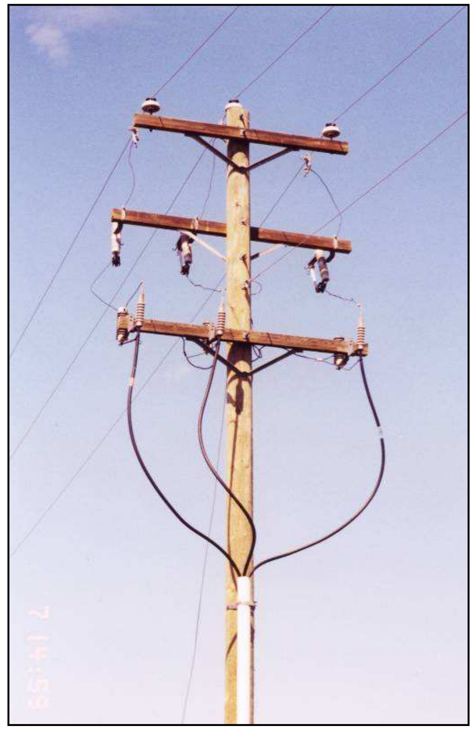


Figure A16. Three-phase overhead to underground riser pole (3UG).

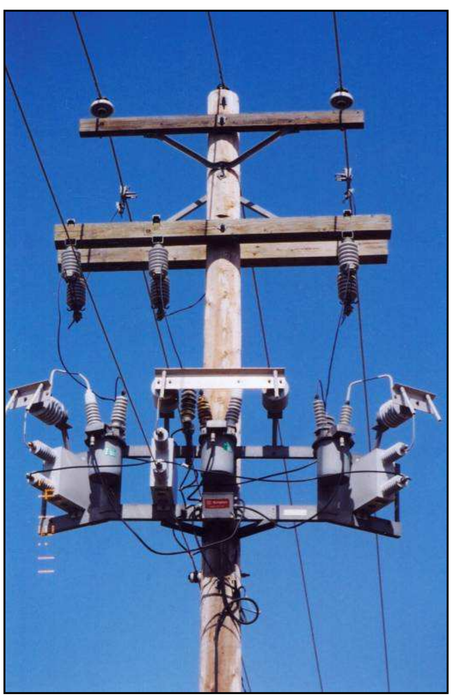


Figure A17. Three-phase capacitor bank (3CB).

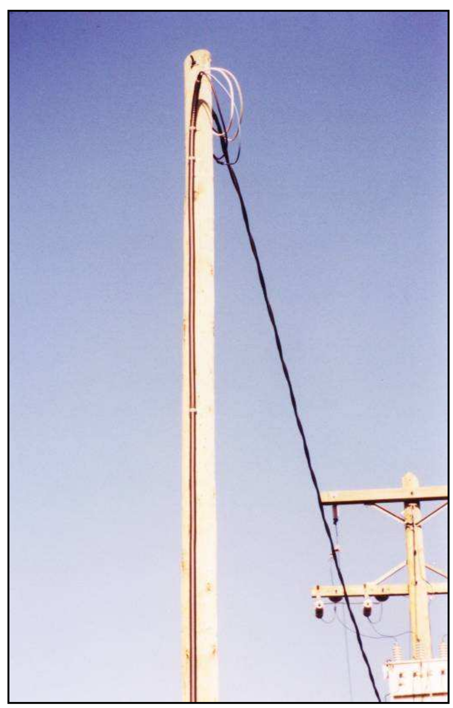


Figure A18. Service pole (SP).

Appendix B. Sample equation of procedure to obtain final mortality estimates (as described in {2.2.6.3)

Calculations to determine equivalent number of townships:

Study area size = 143.7 townships, or 13 400km^2

1. For every township in the study area, the proportion of oilfield, rural and areas with no poles was determined based on ocular estimates of the 1:20 000 and 1:40 000 study area maps.

2. The proportion of oilfield areas was summed for the 143.7 townships. The table below demonstrates this process. The numbers in the “TOTAL” row is the true “equivalent number of townships” that were calculated for the total mortality estimates.

	Proportion Oilfield	Proportion Rural	Proportion No poles	TOTAL
TWP 1	0.00	0.80	0.20	1.00
TWP 2	0.05	0.70	0.25	1.00
TWP 3	0.10	0.90	0.00	1.00
⋮	⋮	⋮	⋮	⋮
TOTAL	**12.67**	**98.13**	**32.89**	**143.67**

Calculations to determine total mortality estimates:

For this example, I will be obtaining the minimum estimate of mortality on three-phase (3XR) structures in oilfield areas using the following information:

- *i* = three phase transformer poles (3XR)
- *j* = oilfields
- A total of 114- 3XR poles were sampled during the survey
- Four confirmed electrocutions were found beneath the 114 – 3XR poles
- 191- 3XR poles were counted within the 21 oilfield sections inventoried
- Within the study area, oilfield regions cover an area equivalent to 12.67 townships in size, or 1181 km^2

1. $\text{MRATE}_i = \dfrac{NO.DEAD_i}{POLES_i}$ [Eq. 2.4]

$\text{MRATE}_{\text{high}}$= 4/114 = 0.035

The average rate of mortality on 3XR poles in oilfields is 0.035 raptors per pole.

2. $\text{AVG.DENS}_{ij} = \dfrac{INV_{ij}}{SEC_j}$ [Eq. 2.5]

AVG.DENS_{ij}= 191/21 = 9.095

The average density of 3XR poles in oilfields is 9.095 per section.

3. $\text{DEAD.SEC}_{ij} = \text{AVG.DENS}_{ij} * \text{MRATE}_i$ [Eq. 2.6]

DEAD.SEC_{ij}= 9.095*0.035 = 0.319

An estimated 0.319 raptors are killed on 3XR poles per oilfield section.

(Note: in Table 2.9, estimates have already been adjusted for scavenging, which multiplied the DEAD.SEC_{ij} estimate by 2.13 (see below). Thus, the above value of 0.319 is displayed as 0.68 in Table 2.9. For the purpose of this example, this scavenging factor is converted at the end.)

4. $\text{DEAD.TWP}_{ij} = \text{DEAD.SEC}_{ij}$ * 36 sections/township [Eq. 2.7]

DEAD.TWP_{ij} = 0.319 *36 = 11.49

An estimated 11.49 raptors are killed on 3XR poles per oilfield township.

5. $DEAD.SA_{ij} = DEAD.TWP_{ij}$ * number of *j*-density townships in the entire study area [Eq. 2.8]

$DEAD.SA_{ij}$ = 11.49 * 12.67 = 145.6

An estimated 145.6 raptors are killed within the oilfield regions in the study area on 3XR poles.

All estimates were multiplied by 2.13 to account for scavenging (assuming 145.6 is 47% of the actual mortality (as discovered during scavenging assessment), the corrected number is 310).

The above calculation is the *minimum* estimate of mortality *in oilfield areas* in the study area *on 3XR poles.*

6. TOTAL.DEAD = $\sum_{j=1}^{2} \sum_{i=1}^{15} DEAD.SA_{ij}$ [Eq. 2.9]

As written in Eq. 2.9, to provide the *total* minimum estimate of mortality on all poles in the study area on 3XR poles (which is based on confirmed electrocutions only), this equation sums:

(1) the estimated *minimum* number of electrocutions on 3XR poles in *high*-density areas (310) and
(2) the estimated *minimum* number of electrocutions on 3XR poles in *rural* areas (14 – calculations not shown here).

This is done for every category of pole.

Similarly, this procedure is done for the total *maximum* estimate of mortality in the study area (which is based on confirmed and unconfirmed electrocutions), to provide the range displayed in Table 2.10.

Appendix C. Sample Raptor Electrocution Form

Observer(s): ___________________
Date of discovery: ___________________
Approximate date & time of incident: ___________________
Case # (pls label bird with this #): ________________________________

POLE LOCATION/IDENTIFICATION

District: _____________________ **Line #:** ______________ **Structure #:** ____________________

Legal Land Description:
____

POLE CONFIGURATION

Please select voltage:
☐ 144 kV ☐ 72 kV ☐ 25kV ☐ 14.4kV ☐ 7.2 kV

Identify Structure type from the Distribution or Transmission Construction Standards Manual:
____

Total # and placement of energized conductors (optional): ______________________________________

Is there a double circuit (optional)? ☐Yes ☐ No
List any mounted equipment (optional):
____

Are there exposed parts (such as cutouts, lightning arresters, jumper wires) (optional)? ☐Yes ☐No
If so, please specify: ____

Are guy wires present? ☐ Yes ☐ No **If so, are they insulated?** ☐Yes ☐ No

Crossarm material: ☐wood ☐ steel ☐ fiberglass

Location of bonding wire: ☐ below crossarm ☐ top of pole ☐ side of pole

Is this structure: ☐old design ☐ new design
Current bird protection on structure (if applicable): ____

Structure Diagram:

Please use the space to the left to draw diagram of structure. On the diagram, please indicate as precisely as possible where the bird made contact with the structure (and/or its equipment) to the best of your knowledge.

Was there something abnormal about the structure that could have contributed to the incident?

___

What damage was caused to the structure by the bird?

___

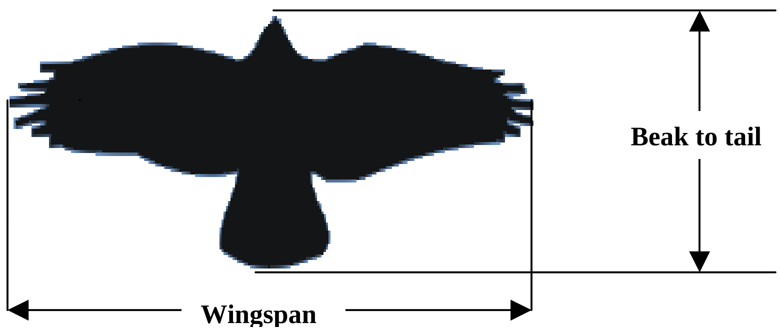
MORTALITIES/INJURIES

**** PLEASE INCLUDE PICTURE OF POLE AND PICTURE OF BIRD (FRONT AND BACK) FOR IDENTIFICATION PURPOSES****
****IF INJURED BIRD FOUND PLEASE CONTACT NEAREST FISH & WILDLIFE OFFICE****

Status: ☐ dead ☐ injured **Number of Individuals** ____ **Location of bird with respect to pole (hanging, distance from base, etc):** ____________________

Family: ☐ Hawk ☐ Eagle ☐ Owl ☐ Falcon ☐ Other: ____________
Species (if known): ____________

Age: ☐ Adult ☐ Juvenile ☐ Unknown **Sex:** ☐ Male ☐ Female ☐Unknown
Please record Wing Spread and Beak to tail distance measures (cm) in the space provided:



Beak to tail distance (cm): _________ **Wingtip to wingtip distance (cm):** _________
Band Number (on leg) (if applicable): ____________

Disposition of carcass (see below): ____________________

****ALL CARCASSES MUST BE BAGGED, LABELLED (LOCATION, DATE), FROZEN AND SENT TO THE FISH & WILDLIFE OFFICE IN FORT MCMURRAY OR STETTLER.**

LIVE SPECIES OBSERVED

Please list any live raptors observed in close proximity to the structure (# and species if possible):

___

___

Please indicate if present on or near pole: ☐Pellets ☐ Whitewash ☐ Prey remains ☐ Nest

☐ Evidence of food supply (gophers, waterfowl, carrion, garbage):____________________

☐ Other:____________________

Appendix D: Data Tables

Table D1. Condensed electrocution evidence survey and preferred pole data (n=379 poles).

Township	Range	Pole #	Pole Category[1]	District[2]	1 PH/ 3PH/SP[3]	Bird Protection	Dist. To Natural Perch (m)	Total Points[4]	Points w/o Whitewash[5]	Habitat[6]	Month[7]	Date	Electrocution evidence[8]	Species represented by evidence[9]	Month	Date	Electrocution evidence[8]	Species represented by evidence[9]
38	20	1	3TG	ST	3PH	N	150	0	0	CR	JN	1	N		JL	6	N	
38	20	2	1FU	ST	3PH	N	150	0	0	CR	JN	1	N		JL	6	N	
38	20	3	3TG	ST	3PH	N	75	1	0	CR	JN	1	N		JL	6	N	
38	20	4	3TG	ST	3PH	N	120	1	1	CR	JN	1	N		JL	6	N	
38	20	5	1FU	ST	3PH	N	220	2	1	CR	JN	1	N		JL	6	N	
38	20	6	3TG	ST	3PH	N	320	0	0	CR	JN	1	N		JL	6	N	
38	20	7	1FU	ST	3PH	N	75	2	0	HS	JN	1	N		JL	9	N	
38	20	8	1FU	ST	3PH	N	40	0	0	PA	JN	1	N		JL	9	N	
38	20	9	3TG	ST	3PH	N	30	2	0	PA	JN	1	N		JL	9	N	
38	20	10	3FU	ST	3PH	N	30	1	0	PA	JN	1	N		JL	9	N	
38	20	11	3DE	ST	3PH	N	40	1	0	PA	JN	1	N		JL	9	N	
38	20	12	3TG	ST	3PH	N	175	1	1	PA	JN	1	N		JL	9	N	
38	20	13	3XR	ST	3PH	N	150	5	1	PA	JN	1	N		JL	9	N	
38	20	14	3TG	ST	3PH	N	35	2	0	PA	JN	1	N		JL	9	N	
38	20	15	3FU	ST	3PH	N	80	5	0	PA	JN	1	N		JL	9	N	
38	20	16	3TG	ST	3PH	N	57.5	3	0	CR	JN	1	N		JL	9	N	
38	20	17	3XR	ST	3PH	Y	10	1	0	AP	JN	1	N		JL	9	N	
38	20	18	3TG	ST	3PH	N	150	5	0	PA	JN	2	N		JL	9	N	
38	20	19	3TG	ST	3PH	N	75	0	0	PA	JN	2	N		JL	9	N	
38	20	20	3TG	ST	3PH	N	150	0	0	PA	JN	2	N		JL	9	N	
38	20	21	1XR	ST	3PH	N	250	4	1	PA	JN	2	N		JL	9	N	
37	20	1	3TG	ST	3PH	N	50	1	0	PA	JN	2	N		JL	9	N	
37	20	2	3DE	ST	3PH	N	30	2	0	PA	JN	2	N		JL	9	RU	GHOW
37	20	3	3DE	ST	3PH	N	20	1	0	PA	JN	2	N		JL	10	N	

[1] Categories as described as Table 2.2
[2] ST = Stettler; FB = Forestburg; CO = Consort
[3] 1PH = single-phase; 3PH = three-phase; SP = service pole
[4] Total raptor use points based on evidence of whitewash, pellets and prey remains. 0 = no use; 9 = high use
[5] Total raptor use points based on evidence of pellets and prey remains. 0 = no use; 6 = high use
[6] AP = aspen parkland; CR = cropland; HS = human settlement; PA = pasture
[7] JN = June; JL = July; AG = August
[8] RC = confirmed raptor; RU = unconfirmed raptor; OC = other species confirmed; OU = other species unconfirmed
[9] AMCR = American crow; BBMA = black-billed magpie; CORA = common raven; GHOW = great horned owl; GOEA = golden eagle; NOFL = northern flicker (*Colaptes auratus*); RTHA = red-tailed hawk; STGR = sharp-tailed grouse (*Tympanuchus phasianellus*); U = unable to identify

Table D1 (con't). Condensed electrocution evidence survey and preferred pole data.

Township	Range	Pole #	Pole Category[1]	District[2]	1 PH/ 3PH/SP[3]	Bird Protection	Dist. To Natural Perch (m)	Total Points[4]	Points w/o Whitewash[5]	Habitat[6]	Month[7]	Date	Electrocution evidence[8]	Species represented by evidence[9]	Month	Date	Electrocution evidence[8]	Species represented by evidence[9]
37	20	4	3XR	ST	3PH	Y	150	4	0	PA	JN	2	N		JL	10	N	
37	20	5	3TG	ST	3PH	N	30	1	0	PA	JN	2	N		JL	10	N	
37	20	6	3FU	ST	3PH	N	65	1	0	PA	JN	2	N		JL	10	N	
37	20	7	3DEM	ST	3PH	N	150	0	0	PA	JN	2	N		JL	10	RC	GHOW
37	20	8	3DE	ST	3PH	N	40	1	0	PA	JN	2	N		JL	10	N	
37	20	9	1XR	ST	3PH	Y	210	4	2	PA	JN	2	N		JL	10	N	
37	20	10	3DEM	ST	3PH	N	210	4	0	PA	JN	2	N		JL	10	N	
37	20	11	3DE	ST	3PH	N	220	2	0	PA	JN	2	N		JL	10	N	
37	20	12	3XR	ST	3PH	Y	120	4	1	PA	JN	2	N		JL	10	N	
37	20	13	1SP	ST	SP	N	70	3	0	PA	JN	2	N		JL	10	N	
37	20	14	3TG	ST	3PH	N	25	1	0	PA	JN	2	N		JL	10	N	
37	20	15	1DE	ST	3PH	N	138	6	1	PA	JN	2	N		JL	10	N	
37	20	16	1XR	ST	1PH	N	300	3	0	PA	JN	2	N		JL	10	N	
37	20	17	3DD	ST	3PH	N	300	3	1	PA	JN	2	N		JL	10	N	
37	20	18	3XR	ST	3PH	N	15	7	1	PA	JN	2	N		JL	11	N	
37	20	19	1FU	ST	3PH	N	25	0	0	PA	JN	3	N		JL	11	N	
37	20	20	1XR	ST	3PH	N	220	3	0	PA	JN	3	N		JL	11	N	
37	20	21	3TG	ST	3PH	N	100	2	0	AP	JN	3	N		JL	11	N	
36	20	1	3RC	ST	3PH	N	400	1	0	CR	JN	3	N		JL	11	N	
36	20	2	3FU	ST	3PH	N	200	4	0	CR	JN	3	N		JL	11	N	
36	20	3	3TG	ST	3PH	N	200	5	0	PA	JN	3	N		JL	11	N	
36	20	4	3TG	ST	3PH	N	300	1	0	PA	JN	3	N		JL	11	N	
36	20	5	3DE	ST	3PH	N	400	1	0	PA	JN	3	N		JL	11	N	
36	20	6	3XR	ST	3PH	Y	200	6	1	PA	JN	3	N		JL	11	N	
36	20	7	1SP	ST	SP	N	220	5	0	PA	JN	3	N		JL	11	OU	BBMA
36	20	8	3XR	ST	3PH	Y	200	7	2	PA	JN	3	N		JL	11	N	
36	20	9	3XR	ST	3PH	Y	40	4	0	PA	JN	3	N		JL	11	N	
36	20	10	3TG	ST	3PH	N	225	3	0	PA	JN	3	N		JL	11	N	
36	20	11	3DD	ST	3PH	N	300	3	0	PA	JN	3	N		JL	11	N	
36	20	12	1SP	ST	SP	N	300	6	4	PA	JN	3	OU	mammal sp.	JL	11	N	
36	20	13	3XR	ST	3PH	N	300	5	2	PA	JN	3	N		JL	11	N	
36	20	14	3XR	ST	3PH	N	400	9	6	PA	JN	3	N		JL	12	N	
36	20	15	3DEM	ST	3PH	N	150	1	0	PA	JN	3	N		JL	12	N	
38	16	1	1SP	ST	SP	N	900	3	0	PA	JN	4	N		JL	7	N	
38	16	2	3DE	ST	3PH	N	1000	1	0	PA	JN	4	N		JL	7	N	
38	16	3	3DE	ST	3PH	N	950	0	0	PA	JN	4	N		JL	7	N	
38	16	4	1SP	ST	SP	N	750	6	1	PA	JN	4	N		JL	7	N	

Table D1 (con't). Condensed electrocution evidence survey and preferred pole data.

Township	Range	Pole #	Pole Category[1]	District[2]	1 PH/ 3PH/SP[3]	Bird Protection	Dist. To Natural Perch (m)	Total Points[4]	Points w/o Whitewash[5]	Habitat[6]	Month[7]	Date	Electrocution evidence[8]	Species represented by evidence[9]	Month	Date	Electrocution evidence[8]	Species represented by evidence[9]
38	16	5	3DEM	ST	3PH	N	750	5	1	PA	JN	4	OU	mammal sp.	JL	7	N	
38	16	6	3TG	ST	3PH	N	950	4	0	PA	JN	4	N		JL	7	N	
38	16	7	3DD	ST	3PH	N	900	5	0	CR	JN	4	OU	STGR	JL	7	N	
38	16	8	3DE	ST	3PH	N	950	1	0	CR	JN	4	N		JL	7	N	
38	16	9	3DD	ST	3PH	N	950	2	0	CR	JN	4	N		JL	7	N	
38	16	10	3XR	ST	3PH	Y	550	1	0	PA	JN	4	OU	Duck sp.	JL	7	N	
38	16	11	3UG	ST	3PH	N	450	1	0	PA	JN	4	N		JL	7	N	
38	16	12	3XR	ST	3PH	Y	350	4	0	PA	JN	4	N		JL	8	N	
38	16	13	3TG	ST	3PH	N	300	3	1	PA	JN	4	N		JL	8	N	
38	16	14	3XR	ST	3PH	N	300	4	0	PA	JN	4	N		JL	8	N	
38	16	15	3TG	ST	3PH	N	87.5	2	1	PA	JN	4	N		JL	8	N	
38	16	16	3DE	ST	3PH	N	87.5	0	0	PA	JN	4	N		JL	8	N	
38	16	17	3FU	ST	3PH	N	70	1	0	PA	JN	4	N		JL	8	N	
38	16	18	3TG	ST	3PH	N	25	3	0	PA	JN	4	N		JL	8	N	
38	16	19	3FU	ST	3PH	N	100	1	0	PA	JN	4	N		JL	8	N	
38	17	1	1XR	ST	1PH	Y	300	3	0	PA	JN	4	N		JL	22	OC	Blackbird sp.
38	17	2	3DD	ST	3PH	N	75	1	0	PA	JN	4	N		JL	22	N	
38	17	3	1TG	ST	3PH	N	25	2	0	PA	JN	4	N		JL	22	N	
38	17	4	3XR	ST	3PH	Y	10	0	0	PA	JN	4	N		JL	22	N	
38	17	5	3XR	ST	3PH	Y	27.5	3	0	CR	JN	4	N		JL	22	N	
38	17	6	1DE	ST	3PH	N	400	4	0	CR	JN	4	N		JL	22	N	
38	17	7	3XR	ST	3PH	Y	200	3	0	PA	JN	4	N		JL	22	OU	Passerine sp.
38	17	8	1SP	ST	SP	N	185	2	0	PA	JN	4	N		JL	22	N	
38	17	9	3TG	ST	3PH	N	200	4	0	PA	JN	4	N		JL	22	N	
38	17	10	3XR	ST	3PH	N	150	4	0	PA	JN	4	N		JL	22	N	
40	10	1	3DD	FB	3PH	N	50	4	0	CR	JN	5	N		JL	17	N	
40	10	2	3DEM	FB	3PH	N	80	0	0	CR	JN	5	N		JL	17	N	
40	10	3	3FU	FB	3PH	N	80	2	0	CR	JN	5	N		JL	17	N	
40	10	4	3XR	FB	3PH	N	175	4	0	CR	JN	5	N		JL	17	OU	AMCR
40	10	5	1SP	FB	SP	N	200	4	0	CR	JN	5	N		JL	17	N	
40	10	6	3XR	FB	3PH	N	200	6	0	CR	JN	5	N		JL	17	N	
40	10	7	3TG	FB	3PH	N	200	0	0	CR	JN	5	RU	RTHA	JL	17	N	
40	10	8	3DE	FB	3PH	N	225	1	0	CR	JN	5	N		JL	17	N	
40	10	9	3DD	FB	3PH	N	250	5	0	CR	JN	5	N		JL	17	OU	Corvid sp.

Table D1 (con't). Condensed electrocution evidence survey and preferred pole data.

Township	Range	Pole #	Pole Category[1]	District[2]	1 PH/ 3PH/SP[3]	Bird Protection	Dist. To Natural Perch (m)	Total Points[4]	Points w/o Whitewash[5]	Habitat[6]	Month[7]	Date	Electrocution evidence[8]	Species represented by evidence[9]	Month	Date	Electrocution evidence[8]	Species represented by evidence[9]
40	10	10	1SP	FB	SP	N	250	4	0	CR	JN	5	N		JL	17	N	
40	10	11	1SP	FB	SP	N	87.5	4	0	CR	JN	5	N		JL	17	N	
40	10	12	3XR	FB	3PH	Y	200	4	0	CR	JN	5	N		JL	17	N	
40	10	13	3XR	FB	3PH	N	100	0	0	CR	JN	5	N		JL	17	N	
40	10	14	3TG	FB	3PH	N	100	0	0	CR	JN	5	N		JL	17	N	
40	10	15	1FU	FB	3PH	N	120	2	0	PA	JN	5	N		JL	17	N	
40	10	16	3FU	FB	3PH	N	100	0	0	PA	JN	5	N		JL	17	N	
40	10	17	3DE	FB	3PH	N	150	0	0	PA	JN	5	RU	Raptor sp.	JL	17	N	
40	10	18	1FU	FB	3PH	N	113	1	0	PA	JN	5	N		JL	17	N	
40	11	1	3XR	FB	3PH	N	150	5	0	CR	JN	5	N		JL	18	N	
40	11	2	3DE	FB	3PH	N	150	4	0	CR	JN	5	N		JL	18	N	
40	11	3	3DE	FB	3PH	N	400	5	0	CR	JN	5	N		JL	18	N	
40	11	4	1DE	FB	1PH	N	250	4	0	PA	JN	5	N		JL	18	N	
40	11	5	3XR	FB	3PH	N	100	5	0	PA	JN	5	N		JL	18	RU	GHOW
40	11	6	3XR	FB	3PH	N	125	1	1	CR	JN	6	N		JL	18	N	
40	11	7	3FU	FB	3PH	N	300	2	0	CR	JN	6	N		JL	18	N	
40	11	8	3TG	FB	3PH	N	325	2	0	CR	JN	6	N		JL	18	N	
40	11	9	3XR	FB	3PH	N	125	7	1	PA	JN	6	N		JL	18	N	
40	11	10	3DE	FB	3PH	N	75	2	0	AP	JN	6	N		JL	18	N	
40	11	11	3XR	FB	3PH	Y	200	6	2	HS	JN	6	OU	mammal sp.	JL	18	N	
40	11	12	1SP	FB	SP	N	200	5	0	HS	JN	6	RU	GHOW	JL	18	N	
40	11	13	3XR	FB	SP	N	45	1	0	CR	JN	6	N		JL	18	N	
40	11	14	1SP	FB	3PH	N	45	3	0	CR	JN	6	N		JL	18	RU	RTHA
40	11	15	1SP	FB	SP	N	50	2	0	PA	JN	6	N		JL	18	N	
40	11	16	3XR	FB	3PH	N	45	6	1	AP	JN	6	N		JL	18	N	
40	11	17	3DD	FB	3PH	N	50	5	0	AP	JN	6	N		JL	18	N	
40	11	18	3XR	FB	3PH	N	70	5	0	AP	JN	6	OC	CORA	JL	18	N	
40	11	19	1SP	FB	SP	N	70	2	0	AP	JN	6	N		JL	18	N	
40	11	20	1SP	FB	SP	N	15	3	1	AP	JN	6	N		JL	18	N	
40	11	21	3XR	FB	3PH	N	25	2	0	AP	JN	6	N		JL	18	N	
40	11	22	3TG	FB	3PH	N	70	4	0	CR	JN	6	N		JL	18	N	
40	11	23	3DE	FB	3PH	N	50	2	0	CR	JN	6	N		JL	18	N	
40	11	24	1SP	FB	SP	N	300	1	0	CR	JN	6	N		JL	18	N	
40	11	25	1SP	FB	SP	N	100	3	0	CR	JN	6	N		JL	18	OU	Corvid sp.
40	11	26	3XR	FB	3PH	Y	100	4	0	CR	JN	6	N		JL	18	N	
40	11	27	3DE	FB	3PH	N	50	0	0	AP	JN	6	N		JL	18	N	

Table D1 (con't). Condensed electrocution evidence survey and preferred pole data.

Township	Range	Pole #	Pole Category[1]	District[2]	1 PH/ 3PH/SP[3]	Bird Protection	Dist. To Natural Perch (m)	Total Points[4]	Points w/o Whitewash[5]	Habitat[6]	Month[7]	Date	Electrocution evidence[8]	Species represented by evidence[9]	Month	Date	Electrocution evidence[8]	Species represented by evidence[9]
40	11	28	3DE	FB	3PH	N	150	1	0	AP	JN	6	N		JL	18	N	
40	11	29	1SP	FB	SP	N	50	4	0	AP	JN	6	N		JL	18	N	
40	11	30	3XR	FB	3PH	Y	100	4	0	CR	JN	6	N		JL	20	N	
40	11	31	3TG	FB	3PH	N	50	5	2	AP	JN	6	N		JL	20	N	
40	11	32	3DD	FB	3PH	N	15	2	0	AP	JN	6	N		JL	20	N	
40	11	33	3FU	FB	3PH	N	50	2	0	AP	JN	6	N		JL	20	N	
40	11	34	3DE	FB	3PH	N	200	1	0	CR	JN	7	N		JL	20	N	
40	11	35	3XR	FB	3PH	N	125	1	0	CR	JN	7	N		JL	20	N	
40	11	36	1SP	FB	SP	N	250	8	3	CR	JN	7	N		JL	20	OU	U
40	11	37	3DD	FB	3PH	N	80	1	0	CR	JN	7	N		JL	20	N	
40	11	38	1DE	FB	1PH	N	100	3	0	CR	JN	7	N		JL	20	OU	U
40	11	39	3XR	FB	3PH	N	150	1	0	CR	JN	7	N		JL	20	N	
40	11	40	3XR	FB	3PH	Y	200	3	0	CR	JN	7	N		JL	20	N	
40	11	41	3UG	FB	3PH	N	275	1	0	CR	JN	7	N		JL	20	N	
40	11	42	3XR	FB	SP	N	60	3	0	CR	JN	7	N		JL	20	OU	U
40	11	43	3FU	FB	3PH	N	150	3	0	CR	JN	7	N		JL	20	N	
40	11	44	3XR	FB	3PH	N	225	3	0	CR	JN	7	N		JL	20	N	
40	11	45	1SP	FB	SP	N	250	4	1	CR	JN	7	N		JL	20	OU	STGR
40	11	46	1SP	FB	3PH	N	200	0	0	CR	JN	7	N		JL	20	N	
40	11	47	3XR	FB	3PH	N	100	4	0	PA	JN	7	N		JL	20	N	
40	11	48	3XR	FB	3PH	N	20	1	0	PA	JN	7	N		JL	20	N	
40	11	49	1SP	FB	SP	N	20	2	0	PA	JN	7	N		JL	20	N	
40	11	50	3DD	FB	3PH	N	20	5	1	PA	JN	7	N		JL	20	N	
40	11	51	3DE	FB	3PH	N	20	0	0	PA	JN	7	N		JL	20	N	
40	11	52	3DE	FB	3PH	N	25	0	0	CR	JN	7	N		JL	20	RU	GHOW
40	11	53	1SP	FB	SP	N	65	3	0	PA	JN	7	N		JL	20	N	
40	11	54	3DE	FB	3PH	N	75	0	0	PA	JN	7	N		JL	20	N	
40	11	55	3XR	FB	3PH	Y	20	2	0	AP	JN	7	N		JL	18	RC	GHOW
40	11	56	3XR	FB	3PH	N	50	2	0	PA	JN	7	N		JL	20	N	
40	11	57	3UG	FB	3PH	N	35	3	0	PA	JN	7	N		JL	21	OU	Passerine sp.
40	11	58	3XR	FB	3PH	Y	20	3	0	PA	JN	7	N		JL	21	N	
40	11	59	3XR	FB	3PH	Y	50	0	0	PA	JN	7	N		JL	21	OC	AMCR
40	11	60	3DE	FB	3PH	N	70	0	0	PA	JN	7	N		JL	21	N	
40	11	61	3XR	FB	3PH	N	200	1	0	PA	JN	8	N		JL	21	OU	U
40	11	62	3XR	FB	3PH	N	150	4	0	PA	JN	8	N		JL	21	N	
40	11	63	1SP	FB	SP	N	200	5	1	PA	JN	8	N		JL	21	N	

Table D1 (con't). Condensed electrocution evidence survey and preferred pole data.

Township	Range	Pole #	Pole Category[1]	District[2]	1 PH/ 3PH/SP[3]	Bird Protection	Dist. To Natural Perch (m)	Total Points[4]	Points w/o Whitewash[5]	Habitat[6]	Month[7]	Date	Electrocution evidence[8]	Species represented by evidence[9]	Month	Date	Electrocution evidence[8]	Species represented by evidence[9]
40	11	64	3TG	FB	3PH	N	30	0	0	PA	JN	8	N		JL	21	N	
40	11	65	3TG	FB	3PH	N	10	1	0	AP	JN	8	N		JL	21	N	
40	11	66	3DE	FB	3PH	N	15	1	0	AP	JN	8	N		JL	21	N	
40	11	67	3DE	FB	3PH	N	32.5	0	0	PA	JN	8	N		JL	21	N	
40	11	68	3UG	FB	3PH	N	300	4	0	PA	JN	8	N		JL	21	N	
40	11	69	3FU	FB	3PH	N	125	4	0	PA	JN	8	N		JL	21	N	
40	11	70	3TG	FB	3PH	N	15	2	0	AP	JN	8	N		JL	21	N	
40	11	71	3UG	FB	3PH	N	200	5	1	CR	JN	8	N		JL	21	N	
36	4	1	1SP	CO	SP	N	500	1	0	PA	JN	13	RU	Raptor sp.	JL	29	OU	STGR
36	4	2	3XR	CO	3PH	Y	500	2	0	PA	JN	13	N		JL	29	N	
36	4	3	3TG	CO	3PH	N	600	4	0	PA	JN	13	N		JL	29	N	
36	4	4	3XR	CO	3PH	Y	400	5	0	CR	JN	13	N		JL	29	N	
36	4	5	3DEM	CO	3PH	N	400	4	0	CR	JN	13	N		JL	29	OU	U
36	4	6	3XR	CO	3PH	Y	600	1	0	CR	JN	13	N		JL	29	N	
36	4	7	1SP	CO	SP	N	550	0	0	PA	JN	13	N		JL	29	N	
36	4	8	3DE	CO	3PH	N	350	5	1	CR	JN	14	N		JL	29	N	
36	4	9	3XR	CO	3PH	Y	450	6	0	CR	JN	14	N		JL	29	OU	AMCR
36	4	10	3XR	CO	3PH	Y	300	6	0	CR	JN	14	N		JL	29	OU	Corvid sp.
36	4	11	3TG	CO	3PH	N	350	5	1	PA	JN	14	N		JL	29	OU	U
36	4	12	3CR	CO	3PH	N	200	5	1	PA	JN	14	N		JL	29	N	
36	4	13	1SP	CO	SP	N	200	6	4	PA	JN	14	N		JL	29	RU	GHOW
36	4	14	3XR	CO	3PH	Y	10	6	0	CR	JN	14	N		JL	29	N	
36	4	15	1SP	CO	SP	N	7.5	2	0	CR	JN	14	N		JL	29	N	
36	4	16	3XR	CO	3PH	Y	600	3	0	CR	JN	14	N		JL	30	N	
36	4	17	3CR	CO	3PH	N	500	4	1	CR	JN	14	N		JL	30	N	
36	4	18	3XR	CO	3PH	Y	600	5	0	CR	JN	14	N		JL	30	N	
36	4	19	3FU	CO	3PH	N	700	1	0	CR	JN	14	N		JL	30	N	
36	4	20	3DE	CO	3PH	N	1100	0	0	CR	JN	14	N		JL	30	N	
36	4	21	3XR	CO	3PH	Y	400	4	0	CR	JN	14	N		JL	30	N	
36	4	22	1SP	CO	SP	N	450	3	0	CR	JN	14	N		JL	30	N	
36	4	23	3XR	CO	3PH	Y	600	4	0	CR	JN	14	N		JL	30	N	
36	4	24	1SP	CO	SP	N	800	4	2	PA	JN	14	OU	U	JL	30	N	
36	4	25	3XR	CO	3PH	N	800	0	0	PA	JN	14	N		JL	30	N	
36	4	26	3XR	CO	3PH	Y	800	1	0	PA	JN	14	N		JL	30	N	
36	4	27	1SP	CO	SP	N	700	0	0	PA	JN	14	N		JL	30	OU	U
36	4	28	3XR	CO	3PH	Y	700	7	3	PA	JN	14	OC	Corvid sp.	JL	30	N	

Table D1 (con't). Condensed electrocution evidence survey and preferred pole data.

Township	Range	Pole #	Pole Category[1]	District[2]	1 PH/ 3PH/SP[3]	Bird Protection	Dist. To Natural Perch (m)	Total Points[4]	Points w/o Whitewash[5]	Habitat[6]	Month[7]	Date	Electrocution evidence[8]	Species represented by evidence[9]	Month	Date	Electrocution evidence[8]	Species represented by evidence[9]
36	4	29	3XR	CO	3PH	Y	700	1	0	PA	JN	14	N		JL	30	N	
36	4	30	1SP	CO	SP	N	700	1	0	PA	JN	14	N		JL	30	N	
36	4	31	3XR	CO	3PH	Y	500	2	0	PA	JN	14	N		JL	30	RC	RTHA
36	4	32	3DE	CO	3PH	N	600	3	0	PA	JN	14	N		JL	30	OU	BBMA
36	4	33	3XR	CO	3PH	Y	700	3	0	PA	JN	14	N		JL	30	N	
36	4	34	3XR	CO	3PH	Y	800	9	4	PA	JN	14	N		JL	30	N	
36	4	35	1SP	CO	SP	N	700	4	2	PA	JN	14	N		JL	30	N	
36	4	36	3CR	CO	3PH	N	1000	3	0	PA	JN	15	N		JL	30	N	
36	4	37	3TG	CO	3PH	N	1000	0	0	PA	JN	15	N		JL	30	N	
36	4	38	3DE	CO	3PH	N	1000	1	0	PA	JN	15	N		JL	30	N	
36	4	39	3XR	CO	3PH	N	800	4	1	PA	JN	15	N		JL	30	N	
36	4	40	3DD	CO	3PH	N	700	6	2	PA	JN	15	N		JL	30	OU	U
36	4	41	3DE	CO	3PH	N	900	3	0	PA	JN	15	N		JL	30	N	
36	4	42	3DE	CO	3PH	N	900	1	0	PA	JN	15	N		JL	30	N	
36	4	43	3DE	CO	3PH	N	1000	1	0	PA	JN	15	N		JL	30	N	
36	4	44	1SP	CO	SP	N	1000	1	0	PA	JN	15	RU	RTHA	JL	30	OU	U
36	4	45	3XR	CO	3PH	Y	500	4	0	PA	JN	15	N		JL	30	RC	RTHA
36	4	46	1SP	CO	SP	N	700	4	2	PA	JN	15	N		JL	30	N	
36	4	47	3XR	CO	3PH	N	50	3	1	PA	JN	15	OU	BBMA	JL	30	OU	Duck sp.
36	4	48	3XR	CO	3PH	Y	300	6	0	PA	JN	15	OU	BBMA	JL	30	OU	Corvid sp.
36	4	49	3DD	CO	3PH	N	150	6	0	PA	JN	15	N		JL	30	N	
36	4	50	3TG	CO	3PH	N	30	3	1	PA	JN	15	N		JL	30	N	
36	4	51	3XR	CO	3PH	Y	100	2	2	PA	JN	15	RU	Raptor sp.	JL	30	OU	Corvid sp.
36	4	52	3DD	CO	3PH	N	100	9	2	PA	JN	15	N		JL	31	OU	Corvid sp.
36	4	53	3XR	CO	3PH	Y	100	2	0	PA	JN	15	N		JL	31	RU	GHOW
36	4	54	3XR	CO	3PH	Y	175	3	1	PA	JN	15	N		JL	31	RU	GHOW
36	4	55	3DE	CO	3PH	N	100	2	0	PA	JN	15	OC	BBMA	JL	31	RU	GHOW
36	4	56	3TG	CO	3PH	N	350	4	2	PA	JN	15	N		JL	31	N	
36	4	57	3XR	CO	3PH	Y	600	4	1	PA	JN	15	N		JL	31	N	
36	4	58	3DE	CO	3PH	N	800	3	1	PA	JN	16	OU	BBMA	JL	31	N	
36	4	59	3XR	CO	3PH	Y	800	6	0	PA	JN	16	OU	Corvid sp.	JL	31	N	
36	5	1	3XR	CO	3PH	Y	450	4	0	PA	JN	16	N		JL	31	N	
36	5	2	3XR	CO	3PH	N	300	6	1	PA	JN	16	N		JL	31	OU	Corvid sp.
36	5	3	3DE	CO	3PH	N	250	1	0	PA	JN	16	N		JL	31	N	
36	5	4	3XR	CO	3PH	N	163	7	0	PA	JN	16	N		JL	31	N	
36	5	5	3DE	CO	3PH	N	200	1	0	PA	JN	16	N		JL	31	OU	Corvid sp.
36	5	6	1DD	CO	1PH	N	50	4	1	PA	JN	16	OU	Gull sp.	JL	31	RU	Raptor sp.

Table D1 (con't). Condensed electrocution evidence survey and preferred pole data.

Township	Range	Pole #	Pole Category[1]	District[2]	1 PH/ 3PH/SP[3]	Bird Protection	Dist. To Natural Perch (m)	Total Points[4]	Points w/o Whitewash[5]	Habitat[6]	Month[7]	Date	Electrocution evidence[8]	Species represented by evidence[9]	Month	Date	Electrocution evidence[8]	Species represented by evidence[9]
36	5	7	1SP	CO	SP	N	60	4	0	HS	JN	16	N		JL	31	RU	Raptor sp.
36	5	8	1SP	CO	SP	N	100	4	0	HS	JN	16	N		JL	31	OU	U
36	5	9	3FU	CO	3PH	N	350	1	0	PA	JN	16	N		JL	31	N	
36	5	10	3FU	CO	3PH	N	450	3	0	PA	JN	16	N		JL	31	N	
36	5	11	3DE	CO	3PH	N	350	1	0	PA	JN	16	OU	Passerine sp.	JL	31	N	
36	5	12	3DE	CO	3PH	N	350	4	0	PA	JN	16	N		JL	31	N	
36	5	13	3XR	CO	3PH	Y	400	4	0	PA	JN	16	N		JL	31	N	
36	5	14	3XR	CO	3PH	N	250	4	0	PA	JN	16	N		JL	31	N	
36	5	15	3DE	CO	3PH	N	275	2	0	PA	JN	16	N		JL	31	N	
36	5	16	3XR	CO	3PH	Y	150	7	2	PA	JN	16	N		JL	31	N	
36	5	17	3DE	CO	3PH	N	150	0	0	PA	JN	16	N		JL	31	N	
36	5	18	3DE	CO	3PH	N	160	3	0	PA	JN	16	N		JL	31	N	
36	5	19	3DE	CO	3PH	N	125	3	0	PA	JN	16	N		JL	31	N	
36	5	20	3DE	CO	3PH	N	125	3	0	PA	JN	16	N		JL	31	N	
36	5	21	3XR	CO	3PH	N	150	6	0	PA	JN	16	OU	Corvid sp.	JL	31	N	
36	5	22	3XR	CO	3PH	N	350	8	3	PA	JN	16	OU	BBMA	JL	31	RU	GHOW
36	5	23	3CR	CO	3PH	N	425	1	0	PA	JN	16	N		JL	31	N	
36	5	24	3DE	CO	3PH	N	425	8	3	PA	JN	17	N		JL	31	OU	Corvid sp.
36	5	25	3XR	CO	3PH	Y	300	8	1	PA	JN	17	N		JL	31	OU	Corvid sp.
36	5	26	3DD	CO	3PH	N	250	4	0	PA	JN	17	N		AG	1	N	
36	5	27	3FU	CO	3PH	N	225	3	0	PA	JN	17	OC	BBMA	AG	1	N	
36	5	28	3DE	CO	3PH	N	400	6	1	PA	JN	17	N		AG	1	N	
36	5	29	3TG	CO	3PH	N	300	5	0	PA	JN	17	N		AG	1	N	
36	5	30	3XR	CO	3PH	Y	100	7	0	PA	JN	17	N		AG	1	OU	AMCR
37	4	1	3DE	CO	3PH	N	400	3	1	PA	JN	17	N		AG	1	N	
37	4	2	3TG	CO	3PH	N	300	1	0	PA	JN	17	N		AG	1	N	
37	4	3	3XR	CO	3PH	N	100	6	1	PA	JN	17	OU	NOFL	AG	1	N	
37	4	4	3XR	CO	3PH	N	100	5	1	PA	JN	17	OU	mammal sp.	AG	1	N	
36	5	31	3DE	CO	3PH	N	200	5	1	PA	JN	18	OU	CORA	AG	1	N	
36	5	32	3XR	CO	3PH	Y	250	9	3	PA	JN	18	OU	BBMA	AG	1	OU	Corvid sp.
36	5	33	3TG	CO	3PH	N	200	4	0	PA	JN	18	OU	CORA	AG	1	OU	U
36	5	34	3DD	CO	3PH	N	150	4	0	PA	JN	18	N		AG	1	OU	BBMA
36	5	35	1XR	CO	3PH	N	600	1	0	PA	JN	18	N		AG	1	N	
36	5	36	3XR	CO	3PH	Y	550	3	0	PA	JN	18	N		AG	1	N	
36	5	37	3TG	CO	3PH	N	300	0	0	PA	JN	18	N		AG	1	N	
36	5	38	3DE	CO	3PH	N	325	4	0	PA	JN	18	N		AG	1	N	

Table D1 (con’t). Condensed electrocution evidence survey and preferred pole data.

Township	Range	Pole #	Pole Category[1]	District[2]	1 PH/ 3PH/SP[3]	Bird Protection	Dist. To Natural Perch (m)	Total Points[4]	Points w/o Whitewash[5]	Habitat[6]	Month[7]	Date	Electrocution evidence[8]	Species represented by evidence[9]	Month	Date	Electrocution evidence[8]	Species represented by evidence[9]
36	5	39	3FU	CO	3PH	N	300	1	0	PA	JN	18	N		AG	1	OU	Sparrow sp.
36	5	40	3FU	CO	3PH	N	450	1	0	PA	JN	18	OU	Passerine sp.	AG	1	N	
36	5	41	3XR	CO	3PH	Y	300	5	0	PA	JN	18	N		AG	1	N	
36	5	42	3DE	CO	3PH	N	400	3	0	PA	JN	18	OU	BBMA	AG	1	OU	U
36	5	43	3DE	CO	3PH	N	350	0	0	PA	JN	18	N		AG	1	N	
36	5	44	3DE	CO	3PH	N	400	3	3	PA	JN	18	N		AG	1	N	
36	5	45	3FU	CO	3PH	N	250	1	0	PA	JN	18	N		AG	1	N	
36	5	46	3XR	CO	3PH	Y	200	6	0	PA	JN	18	N		AG	1	N	
36	5	47	3FU	CO	3PH	N	150	2	0	PA	JN	18	N		AG	2	N	
36	5	48	1SP	CO	SP	N	225	5	0	PA	JN	18	OU	U	AG	2	OU	Blackbird sp.
36	5	49	1SP	CO	SP	N	413	0	0	PA	JN	18	N		AG	2	N	
36	5	50	3XR	CO	3PH	Y	413	1	0	PA	JN	18	N		AG	2	OC	BBMA
36	5	51	3DD	CO	3PH	N	400	2	0	PA	JN	18	N		AG	2	N	
36	5	52	3XR	CO	3PH	Y	250	4	0	PA	JN	19	N		AG	2	N	
36	5	53	3TG	CO	3PH	N	300	3	0	PA	JN	19	N		AG	2	N	
36	5	54	3XR	CO	SP	N	350	2	2	PA	JN	19	RU	Raptor sp.	AG	2	RC	RTHA
36	5	55	3FU	CO	3PH	N	650	1	0	PA	JN	19	RU	GOEA	AG	2	N	
36	5	56	3DD	CO	3PH	N	750	2	2	PA	JN	19	RC	GHOW	AG	2	N	
36	5	57	3DE	CO	3PH	N	700	0	0	PA	JN	19	N		AG	2	N	
36	5	58	3FU	CO	3PH	N	725	2	0	PA	JN	19	N		AG	2	N	
36	5	59	3DE	CO	3PH	N	1100	4	0	PA	JN	19	N		AG	2	N	
36	5	60	3XR	CO	3PH	Y	1100	5	1	PA	JN	19	N		AG	2	N	
36	5	61	3DE	CO	3PH	N	800	2	1	PA	JN	19	N		AG	2	N	
36	5	62	3XR	CO	3PH	Y	850	5	1	PA	JN	19	N		AG	2	N	
36	5	63	1SP	CO	SP	N	850	2	1	PA	JN	19	N		AG	2	N	
36	5	64	3TG	CO	3PH	N	1100	3	2	PA	JN	19	N		AG	2	N	
38	17	11	1FU	ST	1PH	N	80	0	0	PA	JN	24	N		AG	7	N	
38	17	12	3DE	ST	3PH	N	125	5	1	PA	JN	24	N		AG	7	N	
38	17	13	3TG	ST	3PH	N	87.5	0	0	PA	JN	24	N		AG	7	N	
38	17	14	3XR	ST	3PH	N	100	3	0	PA	JN	24	N		AG	7	N	
38	17	15	3FU	ST	3PH	N	100	3	0	CR	JN	24	N		AG	7	N	
38	17	16	3TG	ST	3PH	N	250	1	0	CR	JN	24	N		AG	7	N	
38	17	17	3DD	ST	3PH	N	30	2	0	CR	JN	24	N		AG	7	N	
38	17	18	3XR	ST	3PH	N	50	1	0	CR	JN	24	N		AG	7	N	
38	17	19	3DE	ST	3PH	N	313	2	0	CR	JN	24	N		AG	8	OU	U

Table D1 (con't). Condensed electrocution evidence survey and preferred pole data.

Township	Range	Pole #	Pole Category[1]	District[2]	1 PH/ 3PH/SP[3]	Bird Protection	Dist. To Natural Perch (m)	Total Points[4]	Points w/o Whitewash[5]	Habitat[6]	Month[7]	Date	Electrocution evidence[8]	Species represented by evidence[9]	Month	Date	Electrocution evidence[8]	Species represented by evidence[9]
38	17	20	3DE	ST	3PH	N	350	1	0	CR	JN	24	N		AG	8	N	
38	17	21	3DE	ST	3PH	N	375	2	0	CR	JN	24	N		AG	8	N	
38	17	22	3DD	ST	3PH	N	350	3	0	CR	JN	24	N		AG	8	N	
38	17	23	3XR	ST	3PH	N	350	4	0	CR	JN	24	N		AG	8	RU	GHOW
38	17	24	3TG	ST	3PH	N	90	1	1	PA	JN	25	N		AG	8	N	
38	17	25	3XR	ST	3PH	Y	50	0	0	CR	JN	25	N		AG	7	N	
38	17	26	3DE	ST	3PH	N	175	2	0	PA	JN	25	N		AG	8	N	
38	17	27	1SP	ST	SP	N	300	5	0	CR	JN	25	N		AG	8	N	
38	17	28	1SP	ST	SP	N	150	2	0	CR	JN	25	N		AG	8	N	
38	17	29	3XR	ST	3PH	Y	185	2	1	PA	JN	25	N		AG	8	N	
38	17	30	3DD	ST	3PH	N	100	3	0	PA	JN	25	N		AG	8	N	
38	17	31	3DD	ST	3PH	N	95	3	1	PA	JN	25	N		AG	8	RC	RTHA
38	17	32	3TG	ST	3PH	N	50	2	0	PA	JN	25	N		AG	8	N	
38	17	33	3XR	ST	3PH	N	25	0	0	PA	JN	25	OU	mammal sp.	AG	8	N	
38	17	34	3DE	ST	3PH	N	250	2	0	PA	JN	28	N		AG	8	N	
38	17	35	3DEM	ST	3PH	N	150	2	0	CR	JN	28	N		AG	8	N	
38	17	36	3XR	ST	3PH	Y	300	2	0	CR	JN	28	N		AG	10	N	
38	17	37	1SP	ST	SP	N	300	2	0	CR	JN	28	OU	mammal sp.	AG	10	N	
38	17	38	3XR	ST	3PH	N	200	1	0	CR	JN	28	N		AG	10	N	
38	17	39	3DE	ST	3PH	N	138	2	0	CR	JN	28	N		AG	10	N	
38	17	40	3DE	ST	3PH	N	125	2	0	CR	JN	28	N		AG	10	N	
38	17	41	3TG	ST	3PH	N	150	1	0	CR	JN	28	N		AG	10	N	
37	17	1	3XR	ST	3PH	Y	225	2	0	PA	JN	25	N		AG	10	N	
37	17	2	3DEM	ST	3PH	N	350	4	0	PA	JN	25	N		AG	10	N	
37	17	3	3XR	ST	3PH	Y	300	3	0	PA	JN	25	N		AG	10	N	
37	17	4	3XR	ST	3PH	Y	375	1	0	PA	JN	25	N		AG	11	N	
37	17	5	3DD	ST	3PH	N	200	0	0	PA	JN	25	N		AG	11	N	
37	17	6	3XR	ST	3PH	Y	200	3	0	PA	JN	26	N		AG	11	N	
37	17	7	3CR	ST	3PH	N	138	1	0	PA	JN	26	N		AG	11	N	
37	17	8	3DE	ST	3PH	N	275	1	0	PA	JN	26	N		AG	11	N	
37	17	9	3DE	ST	3PH	N	300	2	0	PA	JN	26	N		AG	13	N	
37	17	10	3XR	ST	3PH	Y	125	4	0	PA	JN	26	N		AG	13	N	
37	17	11	3XR	ST	3PH	Y	125	1	0	PA	JN	26	RU	Raptor sp.	AG	13	N	
37	17	12	3TG	ST	3PH	N	500	2	1	PA	JN	26	N		AG	10	OU	Duck sp.
37	17	13	3DD	ST	3PH	N	700	1	0	PA	JN	26	N		AG	10	N	

Table D1 (con't). Condensed electrocution evidence survey and preferred pole data.

Township	Range	Pole #	Pole Category[1]	District[2]	1 PH/ 3PH/SP[3]	Bird Protection	Dist. To Natural Perch (m)	Total Points[4]	Points w/o Whitewash[5]	Habitat[6]	Month[7]	Date	Electrocution evidence[8]	Species represented by evidence[9]	Month	Date	Electrocution evidence[8]	Species represented by evidence[9]
37	17	14	3DE	ST	3PH	N	700	2	0	PA	JN	26	N		AG	10	N	
37	17	15	1SP	ST	SP	N	20	1	0	PA	JN	26	N		AG	10	N	
37	17	16	3XR	ST	3PH	Y	300	4	0	PA	JN	26	N		AG	11	N	
37	17	17	3TG	ST	3PH	N	300	1	0	PA	JN	26	N		AG	11	N	
37	17	18	1SP	ST	SP	N	325	0	0	PA	JN	26	N		AG	11	N	
37	17	19	3DD	ST	3PH	N	200	1	0	PA	JN	26	N		AG	11	N	
37	17	20	3DD	ST	3PH	N	50	4	0	PA	JN	26	OU	BBMA	AG	11	N	
37	17	21	3TG	ST	3PH	N	100	9	6	PA	JN	26	N		AG	11	N	
37	17	22	3XR	ST	3PH	Y	75	9	2	CR	JN	27	N		AG	11	N	
37	17	23	3TG	ST	3PH	N	225	6	1	PA	JN	27	N		AG	11	N	
37	17	24	3XR	ST	3PH	Y	225	4	0	PA	JN	27	N		AG	11	N	
37	17	25	3DE	ST	3PH	N	275	0	0	PA	JN	27	N		AG	11	N	
37	17	26	3TG	ST	3PH	N	500	1	0	PA	JN	27	N		AG	13	N	
37	17	27	3DE	ST	3PH	N	100	1	0	PA	JN	27	N		AG	13	N	
37	17	28	3TG	ST	3PH	N	30	0	0	AP	JN	27	N		AG	13	N	
37	17	29	3FU	ST	3PH	N	125	2	0	PA	JN	27	N		AG	21	N	
37	17	30	3FU	ST	3PH	N	100	4	0	PA	JN	27	N		AG	21	N	
37	17	31	3DE	ST	3PH	N	100	1	0	PA	JN	27	N		AG	21	RU	RTHA
37	17	32	3XR	ST	3PH	Y	100	4	0	PA	JN	27	N		AG	21	OU	U
37	17	33	3XR	ST	3PH	Y	250	0	0	PA	JN	27	N		AG	21	N	
37	17	34	3DE	ST	3PH	N	350	1	0	PA	JN	27	N		AG	21	N	
37	17	35	3XR	ST	3PH	Y	100	5	1	PA	JN	27	N		AG	21	N	
37	17	36	1SP	ST	SP	N	100	1	0	PA	JN	27	N		AG	21	OU	BBMA
38	16	21	3XR	ST	3PH	Y	200	3	0	HS	JN	28	N		AG	22	N	
38	16	22	3DD	ST	3PH	N	100	3	0	CR	JN	28	N		AG	22	N	
38	16	23	3TG	ST	3PH	N	25	3	0	PA	JN	28	N		AG	22	N	
38	16	24	3TG	ST	3PH	N	288	0	0	CR	JN	28	N		AG	22	N	
38	16	25	1SP	ST	SP	N	200	3	0	CR	JN	28	N		AG	22	N	
38	16	26	3TG	ST	3PH	N	400	4	0	CR	JN	28	N		AG	22	OU	Corvid sp.
38	16	27	3XR	ST	3PH	N	300	6	1	PA	JN	28	N		AG	22	RU	Raptor sp.
38	16	28	1SP	ST	SP	N	150	2	0	CR	JN	28	N		AG	22	N	
38	16	29	3TG	ST	3PH	N	100	5	0	CR	JN	28	N		AG	22	N	
38	16	30	3DE	ST	3PH	N	100	1	0	PA	JN	28	N		AG	22	N	

Table D2. Scavenging assessment data.

Chicken	Large Mammal Burrows[1]	Day carcass discovered gone
1	N	29
2	N	14
3	N	>35
4	Y	>35
5	N	6
6	N	>35
7	Y	>35
8	Y	29
9	N	14
10	N	6
11	N	14
12	Y	>35
13	N	1
14	N	6
15	Y	6
16	Y	2
17	Y	5
18	N	7
19	N	6
20	Y	5
21	Y	4
22	N	5
23	N	35
24	Y	6
25	Y	5
26	Y	4
27	N	1
28	Y	14
29	Y	2
30	N	3
31	N	5
32	Y	3
33	Y	2
34	Y	7
35	N	35
36	N	>35
37	N	>35
38	Y	5
39	N	14
40	Y	>35
41	N	14
42	Y	1
43	N	1
44	Y	6

Table D2 (con't). Scavenging assessment data.

Chicken #	Large Mammal Burrows[1]	Day carcass discovered gone
45	N	3
46	N	4
47	N	>35
48	N	>35
49	N	>35
50	N	4

[1] Presence of large mammal burrows within the 10m radius of the pole

Table D3. Inventory data of 21 oilfield and 18 rural sections. Structure categories as described in Table 2.2.

		Structure Category																			
	Section[1]	3XR	3FU	3DE	3CR	3TG	3UG	3RC	3DD	3CB	3DEM	SP	1XR	1FU	1DE	1CR	1TG	1RC	1DD	1RB	TOTAL
Stettler: oilfield	**29-38-16**	6	2	1	0	37	1	0	4	0	3	5	0	1	0	0	0	0	0	0	**60**
	30-38-16	4	2	2	0	13	0	0	2	0	0	4	0	0	0	0	0	0	0	0	**27**
	04-38-17	7	0	8	0	15	0	0	1	0	1	10	1	0	4	0	17	0	0	0	**64**
	06-38-17	2	2	2	0	16	0	0	3	0	0	4	1	1	2	0	13	0	0	0	**46**
	08-38-17	9	0	9	0	27	0	0	4	0	0	10	1	1	0	0	0	0	1	0	**62**
	36-38-17	1	1	2	0	3	0	0	1	0	0	1	0	0	0	0	0	0	0	0	**9**
	31-37-17	18	2	15	1	42	0	0	9	0	0	18	2	1	1	0	1	0	0	0	**110**
	26-36-20	7	2	6	0	28	0	1	3	0	0	5	1	0	0	0	0	0	0	0	**53**
	02-37-20	5	2	11	0	28	0	0	1	0	3	6	2	2	1	0	9	0	1	1	**72**
	10-38-20	5	3	3	0	45	0	0	0	0	0	5	2	3	2	0	12	0	0	0	**80**
	27-38-20	0	2	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**11**
Forestburg: oilfield	**27-40-10**	4	2	6	0	31	0	0	5	0	1	3	0	2	0	0	0	0	0	0	**54**
	29-40-11	13	1	12	0	12	4	0	3	0	0	13	0	0	0	0	0	0	0	0	**58**
	32-40-11	31	4	20	1	45	5	0	6	0	1	31	0	0	0	0	0	0	0	0	**144**
	36-40-11	1	1	0	0	5	2	0	0	0	0	1	1	0	3	0	0	0	0	0	**14**
Consort: oilfield	**19-36-04**	11	0	7	2	5	4	0	1	0	0	12	0	0	0	0	0	0	0	0	**42**
	30-36-04	19	1	8	2	21	1	0	2	0	0	19	0	0	0	0	0	0	0	0	**73**
	31-36-04	8	1	4	0	10	2	0	2	0	0	8	0	0	0	0	0	0	0	0	**35**
	12-37-04	3	0	3	0	14	0	0	2	0	0	3	0	0	0	0	0	0	0	0	**25**
	25-36-05	21	12	19	0	32	0	0	2	0	0	22	0	0	0	0	0	0	0	0	**108**
	36-36-05	16	4	22	1	35	1	0	3	0	1	20	1	0	1	0	1	0	1	0	**107**

Table D3 (con't). Inventory data of 21 oilfield and 18 rural sections.

	Section[1]	3XR	3FU	3DE	3CR	3TG	3UG	3RC	3DD	3CB	3DEM	SP	1XR	1FU	1DE	1CR	1TG	1RC	1DD	1RB	TOTAL
		Structure Category																			
Stettler: rural	**27-37-20**	1	2	0	0	29	0	0	1	0	1	0	2	5	6	0	3	0	0	0	**50**
	16-37-20 17-37-20	0	0	0	0	0	0	0	0	0	0	1	5	0	5	0	27	0	1	0	**39**
	06-38-21 01-38-22 36-37-22 31-37-21	0	0	0	0	0	0	0	0	0	0	6	9	2	16	0	84	0	3	0	**120**
	13-39-18 14-39-18 23-39-18 24-39-18	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	45	1	2	0	**52**
	20-37-20 21-37-20	0	0	0	0	0	0	0	0	0	0	7	8	2	9	1	50	0	0	0	**77**
	26-37-20	0	1	0	0	15	0	0	0	1	0	4	4	2	2	0	15	0	2	0	**46**
Forestburg: rural	**20-39-13 21-39-13 28-39-13 29-39-13**	0	0	0	0	0	0	0	0	0	0	2	4	1	7	0	49	0	2	0	**65**
	TOTAL	**192**	**47**	**160**	**7**	**517**	**20**	**1**	**55**	**1**	**11**	**221**	**47**	**23**	**59**	**1**	**326**	**1**	**13**	**1**	**1703**

[1] In some cases, a power line would cross multiple inventory sections. In these cases the collective inventory for the multiple sections was done. These multiple sections are grouped between broken lines in the above table. Section numbers are reported as section-township-range. All sections are west of the fourth meridian.

Table D4. Raptor Electrocution Form data from within the study area as reported by ATCO Electric, 04/03 – 12/04 (n=53)[1].

Year	Month	Day	District[2]	Pole category[3]	Existing Bird Protection	Species[4]	Age[5]	Sex[5]	Weight (g)	Location of carcass with respect to pole
2003	Mar	21	FB	1XR	Y	GHOW	U	U		lying on top of XR
2003	Apr	15	CO	3TG	N	RTHA	A	F	1350	1.5m from base of pole
2003	Apr	21	FB	3XR		RTHA	A	F	1450	lying on top of XR
2003	Apr	29	ST	1DE	N	RTHA	A	F	1000	hanging on pole under jumper wire
2003	Apr	29	FB	3XR	Y	RTHA	A	F	1300	2ft from base of pole
2003	Apr	30	CO	3XR	N	RTHA	A	M	1050	2ft from base of pole
2003	May	8	FB	3DE	N	RTHA	A	M	850	1m from base
2003	May	13	ST	3XR	Y	RTHA	U	U		base of pole
2003	May	20	ST	3GA	N	GHOW	A	U		
2003	May	20	CO	3FU	N	RTHA	A	F	1250	1.5m from base of pole
2003	May	20	CA	3XR	N	RTHA	A	U		5 ft from base
2003	June	23	FB	1DE	N	GHOW	A	M	1250	3 ft from base of pole
2003	June	26	CA	1XR		GHOW	J	F	1300	below XR
2003	June	29	FB	3XR	N	GHOW	A	U	1400	lying on top of XR
2003	July	10	FB	3UG	N	GHOW	J	F	1100	2ft from base of pole
2003	July	16	FB	3UG	N	GHOW	J	F	1100	hanging
2003	July	18	ST	1XR	N	GHOW	A	F	1500	base of pole
2003	July	19	CO	3XR	Y	GHOW	J	M	1100	base of pole
2003	July	20	ST	3XR		GHOW	A	F	1350	hanging on Xmer w/ rabbit in talons
2003	July	20	FB	3UG	N	RTHA	A	F	1100	2ft from base of pole
2003	July	26	CA	1DE		GHOW	A	F	1450	base of pole
2003	July	26	CA	1DE		GHOW	J	U	1350	hanging from wire
2003	Aug	15	CO	3FU	N	GHOW	A	F	1450	hung on switch arm
2003	Aug	15	CO	3XR	N	GHOW	J	F		1.5m from base of pole
2003	Aug	20	FB	3XR	N	RTHA	A	U	1050	1m from base

[1] Blank cells indicate that data were not reported
[2] CA = Castor; CO = Consort; FB = Forestburg; ST = Stettler
[3] Pole categories as described in Table 2.2
[4] GHOW = great horned owl; RTHA = red-tailed hawk
[5] U = unknown

Table D4 (con't). Raptor Electrocution Form data from within the study area as reported by ATCO Electric, 04/03 – 12/04 (n=53)[1].

Year	Month	Day	District[2]	Pole category[3]	Existing Bird Protection	Species[4]	Age[5]	Sex[5]	Weight (g)	Location of carcass with respect to pole
2003	Aug	24	FB	3CB	Y	RTHA	A	U		5m from base of pole
2003	Aug	27	FB	1DE	N	GHOW	J	U		hanging
2003	Oct	15	CO	3XR	Y	GHOW	A	F	1270	3 ft from base of pole
2003	Oct	21	ST	3XR	N	GHOW	A	F	1475	lying on top of XR
2003	Oct	22	ST	1XR	N	GHOW	A	F	1650	2m from base of pole
2004	Apr	8	CA	3UG	N	GHOW	U	U		3 ft from base of pole
2004	Apr	21	CO	1DE	N	GHOW	A	F	1525	1m from base
2004	Apr	30	CA	1DD	N	GHOW	A	U		laying across wire and guy wire
2004	May	29	CO	1TG	N	GHOW	U	U		hanging from pole
2004	June	2	CA	3XR	N	RTHA	A	F	1035	hanging from XR
2004	June	9	CO	3XR	N	GHOW	A	M	1285	2m from base of pole
2004	June	10	FB	3UG	N	GHOW	J	U		base of pole
2004	June	25	FB	3XR	N	GHOW	J	M	1090	base of pole
2004	July	5	ST	3XR	N	RTHA	J	F	1070	base of pole
2004	July	5	FB	3UG	N	GHOW	A	F	1400	base of pole
2004	July	5	FB	3XR	Y	GHOW	A	F	1300	hanging from fuse (talons locked with other bird)
2004	July	5	FB	3XR	Y	GHOW	A	F	1300	hanging from fuse (talons locked with other bird)
2004	July	5	FB	3UG	N	RTHA	A	U	1050	base of pole
2004	July	7	CO	3XR	N	RTHA	A	F	1200	2ft from base of pole
2004	July	15	CO	3XR	N	GHOW	J	F	1070	3m from base of pole
2004	July	17	CO	3UG	N	RTHA	A	M	880	2m from base of pole
2004	July	17	FB	3XR	N	GHOW	A	U	1235	
2004	July	17	FB	3XR	N	GHOW	A	M	1030	base of pole
2004	July	29	CA	1XR	N	GHOW	A	M	995	1m from base
2004	Aug	14	FB	3XR	N	RTHA	J	F	1235	
2004	Sept	1	CO	3XR	N	GHOW	A	F	1590	5m from base of pole
2004	Oct	27	CA	3XR	Y	GHOW	A	U		2m from base of pole
2004	Nov	2	CA	1DE	N	GHOW	A	U		hanging from wire

Table D5. Raptor pole use data.

Species[1]	Age[2]	Perch Structure	Pole Cat.[3]	Perch Loc'n[4]	PC or OP[5]
SWHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	J	Pole	SP	2	OP
RTHA	A	Pole	1TG	5	OP
RTHA	A	Pole	3XR	2	OP
RTHA	A	Pole	3XR	6	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
SWHA	A	Pole	3TG	1	OP
SWHA	A	Pole	3DE	1	OP
SWHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	U	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	U	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	U	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP

Table D5 (con't). Raptor pole use data.

Species[1]	Age[2]	Perch Structure	Pole Cat.[3]	Perch Loc'n[4]	PC or OP[5]
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	J	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP

[1] SWHA = Swainson's hawk; RTHA= red-tailed hawk
[2] U = unknown
[3] Pole categories as described as in Table 2.2; Trans = transmission (>69kV) pole; "?" = not reported
[4] Perching location on power pole. 1 = between phase and pole; 2 = top of pole; 3 = on wire next to pole; 4 = between two phases (when two phases on one side); 5 = top of insulator; 6 = on crossarm between two horizontal insulators; 7 = between two lightning arrestors; 8 = on angled crossarm of 144 kV transmission pole; 9 = top crossarm of 3XR; 10 = tree
[5]PC = sighting during point count; OP = opportunistic sighting

Table D5 (con't). Raptor pole use data.

Species[1]	Age[2]	Perch Structure	Pole Cat.[3]	Perch Loc'n[4]	PC or OP[5]
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
SWHA	A	Pole	3TG	1	OP
SWHA	A	Pole	3TG	1	OP
SWHA	A	Pole	3TG	1	OP
SWHA	A	Pole	3TG	1	OP
RTHA	A	Pole	Trans.	1	OP
RTHA	A	Pole	Trans.	1	OP
RTHA	A	Pole	Trans.	1	OP
RTHA	A	Pole	Trans.	1	OP
RTHA	A	Pole	Trans.	1	OP
RTHA	A	Pole	Trans.	1	OP
RTHA	A	Pole	Trans.	1	OP
RTHA	A	Pole	Trans.	1	OP
RTHA	A	Pole	Trans.	1	OP
RTHA	A	Pole	Trans.	1	OP
RTHA	A	Pole	Trans.	1	OP
SWHA	A	Pole	Trans.	1	OP
RTHA	A	Pole	1TG	3	OP
RTHA	A	Pole	1TG	3	OP
SWHA	A	Pole	3DE	6	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP

Table D5 (con't). Raptor pole use data.

Species[1]	Age[2]	Perch Structure	Pole Cat.[3]	Perch Loc'n[4]	PC or OP[5]
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	3TG	1	OP
SWHA	A	Pole	3TG	1	OP
SWHA	A	Pole	3XR	6	OP
RTHA	A	Pole	3TG	1	OP
RTHA	A	Pole	Trans.	8	OP
SWHA	A	Pole	Trans.	4	OP
RTHA	U	Pole	Trans.	4	OP
RTHA	A	Pole	3UG	7	OP
RTHA	A	Pole	1TG	5	OP
RTHA	A	Pole	1TG	3	OP
RTHA	A	Pole	1TG	3	OP
RTHA	A	Pole	1TG	5	OP
SWHA	A	Pole	1TG	5	OP
RTHA	A	Pole	1TG	5	OP
SWHA	A	Pole	1TG	5	OP
SWHA	J	Pole	3TG	5	OP
RTHA	A	Pole	1TG	3	OP
SWHA	A	Pole	1TG	3	OP
SWHA	A	Pole	1TG	3	OP
SWHA	A	Pole	1TG	3	OP
SWHA	A	Pole	3DE	1	OP
RTHA	A	Pole	1DE	3	OP
RTHA	A	Pole	Trans.	1	OP
RTHA	J	Pole	Trans.	1	OP
RTHA	A	Pole	1TG	5	OP
RTHA	A	Pole	Trans.	2	OP
RTHA	A	Pole	1XR	2	OP
RTHA	A	Pole	3TG	2	OP
RTHA	A	Pole	3TG	2	OP
RTHA	A	Pole	Trans.	2	OP
RTHA	J	Pole	3XR	2	OP
SWHA	J	Pole	3XR	2	OP

Table D5 (con't). Raptor pole use data.

Species[1]	Age[2]	Perch Structure	Pole Cat.[3]	Perch Loc'n[4]	PC or OP[5]
SWHA	A	Pole	SP	2	OP
RTHA	A	Pole	3XR	2	OP
SWHA	A	Pole	SP	2	OP
SWHA	A	Pole	3DE	1	OP
SWHA	A	Pole	3DE	1	OP
RTHA	A	Pole	3XR	9	PC
SWHA	A	Pole	3TG	1	PC
SWHA	A	Pole	3TG	1	PC
RTHA	A	Pole	?	9	PC
RTHA	A	Pole	?	9	PC
RTHA	A	Pole	?	9	PC
RTHA	A	Pole	3DE	1	PC
RTHA	A	Pole	3TG	1	PC
SWHA	J	Pole	3XR	6	PC
RTHA	U	Pole	3XR	6	PC
RTHA	A	Pole	3XR	6	PC
RTHA	A	Pole	3TG	1	PC
RTHA	A	Pole	3TG	1	PC
SWHA	J	Pole	3XR	6	PC
SWHA	U	Pole	SP	2	PC
SWHA	U	Pole	3TG	1	PC
RTHA	A	Pole	3DE	1	PC
RTHA	A	Tree		10	OP
SWHA	U	Tree		10	OP
RTHA	U	Tree		10	OP
SWHA	A	Tree		10	OP
RTHA	U	Tree		10	OP
RTHA	A	Tree		10	OP
RTHA	U	Tree		10	OP
RTHA	A	Tree		10	OP
RTHA	A	Tree		10	OP
RTHA	U	Tree		10	OP
RTHA	U	Tree		10	OP

Table D5 (con't). Raptor pole use data.

Species[1]	Age[2]	Perch Structure	Pole Cat.[3]	Perch Loc'n[4]	PC or OP[5]
SWHA	A	Tree		10	OP
RTHA	A	Tree		10	OP
SWHA	A	Tree		10	OP
SWHA	A	Tree		10	OP
RTHA	J	Tree		10	OP
SWHA	A	Tree		10	OP
SWHA	A	Tree		10	OP
SWHA	J	Tree		10	OP
SWHA	J	Tree		10	OP
RTHA	A	Tree		10	OP
RTHA	A	Tree		10	OP
RTHA	U	Tree		10	OP
RTHA	J	Tree		10	OP
RTHA	J	Tree		10	OP
RTHA	J	Tree		10	OP
RTHA	J	Tree		10	OP
RTHA	A	Tree		10	OP
SWHA	A	Tree		10	OP
RTHA	A	Tree		10	OP
RTHA	U	Tree		10	OP
RTHA	U	Tree		10	PC
RTHA	A	Tree		10	PC
RTHA	A	Tree		10	PC
SWHA	A	Tree		10	PC
SWHA	U	Tree		10	PC
RTHA	U	Tree		10	PC
SWHA	U	Tree		10	PC
SWHA	U	Tree		10	PC
RTHA	A	Tree		10	PC
RTHA	U	Tree		10	PC
RTHA	U	Tree		10	PC
SWHA	A	Tree		10	PC
SWHA	A	Tree		10	PC

Table D5 (con't). Raptor pole use data.

Species[1]	Age[2]	Perch Structure	Pole Cat.[3]	Perch Loc'n[4]	PC or OP[5]
SWHA	A	Tree		10	PC
RTHA	A	Tree		10	PC
RTHA	U	Tree		10	PC
RTHA	U	Tree		10	PC
SWHA	U	Tree		10	PC
SWHA	J	Tree		10	PC
SWHA	J	Tree		10	PC
SWHA	U	Tree		10	PC
SWHA	U	Tree		10	PC
SWHA	U	Tree		10	PC