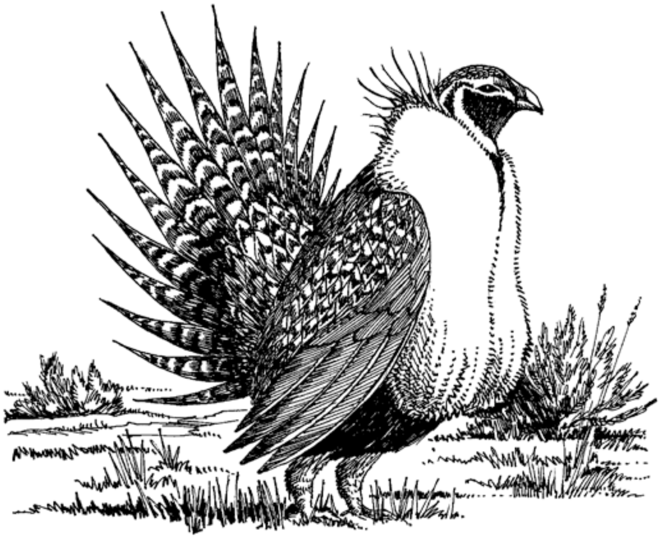
Alberta Greater Sage-grouse Avian Predator Survey



Alberta Species at Risk Report No. 149

Alberta Greater Sage-grouse Avian Predator Survey

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Alberta Environment and Sustainable Resource Development

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EXECUTIVE SUMMARY

A greater sage-grouse avian predator monitoring survey was needed to provide information on distribution, habitat associations, and baseline populations prior to initiation of a sage-grouse predator management program. The survey is designed for repeating in subsequent years once predator management is underway, thereby providing a potential measure of program effectiveness. This report describes the avian predator monitoring protocol and results of the 2013 survey. The survey area is within the current Alberta sage-grouse range, an area of ~3800 km in in the extreme south-eastern corner of the province. The monitoring protocol was designed for collection of data on avian predators, particularly corvids (American crows, black-billed magpies, common ravens). A systematic roadside survey was designed using a series of point samples contributing to a continuous observation zone along a series of 19 road-based transects, each of 10 kilometers length. Point counts were used to allow for detecting and identifying birds by both sight and sound. A three-minute observation and listening period was used. The first minute entailed observation and silent listening followed by broadcasting of electronic corvid and predator calls for the second minute, then silent listening for the third minute. A protocol was included to record habitat and anthropogenic structures at each stop. The data that was collected on habitat and anthropogenic structures was used to provide a habitat classification for each survey stop. The resulting habitat classes were used to derive species-habitat correlations. An initial survey was done in late March 2013. Habitat classifications, photographs, and descriptions of anthropogenic structures were used from that survey. It became evident during the March survey that timing and conditions were not optimal for sampling of avian predators. The survey was redone in early May 2013 for collection of avian predator data. A total of 46 Black-billed magpies, 67 American crows and 3 common ravens were observed on transects in the May survey. This provided abundance index (#birds/10 km) values of 2.42 black-billed magpies, 3.53 American crows and 0.16 common ravens per 10 km. Corvids showed very little use of un-modified native grasslands in the southern Alberta project area, but where anthropogenic structures were present in native grasslands, there was a higher abundance of crows and magpies. Riparian habitats in proximity to anthropogenic features had the strongest positive influence on use by both crows and magpies. There was extremely high selection of these habitats by both species. Occurrence was highest in riparian areas closely associated with farms, residences, and cattle corrals. The native grasslands should be the highest priority areas for removal of anthropogenic structures as they effectively provide predator subsidies in sage-grouse critical habitat. The strong association of avian predators with anthropogenic structures in native grasslands, where they would otherwise not occur, provides strong rationale for doing predator management in these habitats. Riparian areas provide habitat suitability for crows and magpies. The addition of anthropogenic structures greatly increases use of riparian areas by corvids. Where possible and feasible, particularly when in sage-grouse critical habitat, anthropogenic structures should also be removed from riparian habitats.

ACKNOWLEDGEMENTS

This project was developed at the request of Joel Nicholson, Area Species at Risk Biologist with Alberta Environment and Sustainable Resource Development (AESRD). Joel provided contract administration, assisted with the May 2013 surveys, and helped with field accommodation during that survey. Brandy Downey of AESRD assisted with some key equipment needs. Kayla Balderson of AESRD produced a map of critical habitats and leks, which was used in transect design. Robin Gutsell of AESRD provided report formatting information and advice.

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1. INTRODUCTION

The greater sage-grouse *Centrocercus urophasianus* is listed as *endangered* in Alberta's *Wildlife Act* and Canada's *Species at Risk Act*. In 2005 a provincial recovery plan was developed (Alberta Sage-grouse Recovery Action Group 2005). A national recovery strategy was produced in 2001 with an update completed in 2008 (Lungle and Pruss 2008). Recovery actions to date have emphasized mapping of critical habitat as well as habitat protection and voluntary stewardship measures. In spite of these efforts, extremely low population counts in 2010, 2011, 2012 and 2013 suggest imminent extirpation may occur unless immediate direct intervention measures are taken (Nicholson 2013).

A population augmentation project was undertaken in 2011 and 2012 involving transplant of wild sage-grouse. In 2011 and 2012 a cumulative total of 38 female and three male sage-grouse were captured in Montana and released at two active leks in Alberta (Nicholson 2013). The subsequent satellite telemetry monitoring of these birds showed that 11 of the 13 nests that were initiated by these birds failed, with depredation being the cause in all cases (Nicholson 2013). The lack of nesting success led to a decision by Montana Fish Wildlife and Parks to stop providing sage-grouse until the predation risk is reduced.

A sage-grouse avian predator monitoring survey was needed to provide information on distribution, habitat associations, and a measure of baseline populations prior to initiation of a sage-grouse predator management program. The survey is designed for repeating in subsequent years once predator management is underway, thereby providing one potential measure of program effectiveness. This report describes the avian predator monitoring protocol and results of the 2013 surveys.

2. GOALS AND OBJECTIVES

The primary goal is to provide a baseline survey for determining abundance of selected avian predators within the range of greater sage-grouse in Alberta. The survey is to be used as a potential measure of whether subsequent predator management activities influence avian predator numbers. A standardized repeatable survey protocol will provide a basis for estimating trends in numbers of sage-grouse avian predators annually.

A secondary objective is to gain information on distribution and habitat use of avian predators within sage-grouse range. The survey is not designed to provide absolute population estimates of sage-grouse avian predators. Several factors including the large size of the project area and access limitations would make such an objective unachievable with resources available. The design protocol could allow for avian predator density estimations; however, biases introduced by a systematic (non-random) design of this survey and the gregarious behavioural traits of several avian predator species could confound such density estimations. Similarly, the methodology of actively calling birds could inflate derived density estimates. Consistent application of the survey methodology should allow for avian predator trend estimation over a series of years.

3. STUDY AREA

The survey area is within the current Alberta greater sage-grouse range. This is an area of approximately 3800 km in 42 townships in the extreme southeastern corner of the province. A sage-grouse predator management program is planned for part or all of the project area.

4. SURVEY DESIGN CONSIDERATIONS

The following subsections describe the various topics and associated questions that were considered in designing the survey. Pertinent references were reviewed to answer these questions and to produce a survey protocol and design.

4.1. Target Species

The Alberta sage-grouse predator monitoring protocol has been designed for collection of data on avian predators, particularly corvids including American crow *Corvus brachyrhynchos*, black-billed magpie *Pica hudsonia*, and common raven *Corvus corax*, as these are considered to be important sage-grouse nest predators in Alberta (Nicholson 2013). Other potential sage-grouse avian predator species were recorded on the survey, such as great-horned owl *Bubo virginianus*, red-tailed hawk *Buteo jamaicensis*, Swainson's hawk *Buteo swainsoni*, northern harrier *Circus cyaneus*, short-eared owl *Asio flammeus*, ferruginous hawk *Buteo regalis*, golden eagle *Aquila chrysaetos*, and loggerhead shrike *Lanius ludovicianus*. Incidental observations of potential mammalian predators such as red fox *Vulpes vulpes*, striped skunk *Mephitis mephitis*, raccoon *Procyon lotor* and coyote *Canis latrans*, were also recorded.

4.2. Random vs. Systematic Sampling

A random sampling design requires ability to sample anywhere in a project area using randomly selected points or transects (Lancia et al. 2005). The use of existing roads was a pre-determined condition to provide an easily accessible and repeatable survey. This was a logistic consideration that related to practicality, staffing and financial resource availability and it precluded the option of using a random sampling design.
A systematic survey design was developed to incorporate standardized data collection methodology. The selection of systematic roadside surveys is consistent with avian predator surveys in other projects and is generally considered as an acceptable technique for trend surveys (McCarthy et al. 2011). This approach can be used to develop an index of abundance such as number of animals seen per unit of time or distance (World Wildlife Fund 2000).

Crows, magpies and ravens are often found at higher densities along roadsides and near other anthropogenic structures so with surveys being done from roadsides, corvid numbers may be overestimated (Liebezeit and George 2002, Knight and Kawashima 1993, Boarman and Coe 2002, Howe 2012; Bui et al. 2012, Seckel 2011). Systematic roadside surveys would likely sample a higher proportion of the corvid population than random surveys. This could inflate population density and size calculations. The increased numbers observed would, however, provide for more data per transect for use in interpretation of trends. With consistent data collection year-to-year it should be beneficial to use such an approach for trend estimation.

4.3. Mode of Travel

Logistical considerations including financial cost, efficiency of data collection, and access within the project area pre-determined that the mode of travel be truck on roads that are passable under most conditions (i.e., paved and gravel). This limited survey design options by removing parts of the landscape from being considered for transects. As described in the previous section, this effectively removed the option of random sampling, but still allowed for a systematic approach to sampling.

4.4. General Survey Methodology

The sampling methodology incorporated elements of point samples and line transects (Garton et al. 2005; New Zealand Department of Conservation No Date). The design drew upon elements of the North American Breeding Bird Survey (Robbins et al. 1986), sage-grouse predator surveys used in the United States of America (Coates et al. 2007; Howe 2012; Bui et al. 2012; Dinkins et al. 2012; Dzialak et al. 2011) and other corvid surveys (Luginbuhl et al. 2001). The protocol was also influenced by roadside survey methodology designed for other wildlife species in Alberta (Saunders 2001; Downey et al. 2006).

The Alberta sage-grouse avian predator survey was designed to use a series of point samples contributing to a continuous observation zone along a series of 19 road-based transects, each of 10 km length. General survey methodology incorporated the following considerations and assumptions:

- A high degree of visibility would be available in this project area, due to it being comprised mostly of open grassland/farmland habitat;
- A large proportion of corvids and raptors plus objects of interest (habitat or anthropogenic structures) would be observable and identifiable within 500 m of each observation point (see “Detection Procedures”);
- Quick progress of the observer along road transects would be suitable for observing highly-mobile corvids and raptors (see “Length of Observation Period”); and
- As many variables as possible would be kept constant through consistency in survey methodology and timing.

4.5. Observation Technique

Point counts were selected to allow for detecting and identifying birds by both sight and sound. An alternative approach of constantly driving road transects was rejected because it removed the possibility of sound detection of birds as well as the chance of call-playback for luring birds to the observer. This followed early decision of whether the surveyors should engage in active calling of avian sage-grouse predators in addition to being passive observers. Several past surveys of prairie grouse predators in Nevada, Idaho and Wyoming shrub-steppe communities had employed passive observation surveys (Coates 2007, Howe 2012, Bui et al. 2012). In western Washington, Luginbuhl et al. (2001) had added 30-second bursts of electronic corvid territorial calls interspersed with predator attraction calls to maximize chances of seeing and hearing corvids. It was recognized that the use of attractant calls could over-represent corvids at the plot level (by attracting birds into the plot from the surrounding area), but also that they could help in providing predator counts that reflect predation risk at the landscape scale (Luginbuhl et al. 2001). A decision was made to use electronic calls in the Alberta sage-grouse predator surveys to increase the probability of detection of corvids.

4.6. Seasonal Timing

The initial run of surveys was to be done in late March 2013. This timing preceded an anticipated predator management program and corresponded with the sage-grouse pre-nesting period. Due to circumstances encountered on the March survey (including poor access and presence of flocks of late-migrant crows), a decision was made to resurvey in early May. Annual surveys in subsequent years will be scheduled during the early May period. Further elaboration on seasonal timing is provided in the Discussion section of this report.

4.7. Transect Locations and Length

Survey transects were designed to be located near sage-grouse leks and critical habitat. Several transect distances were considered, up to 40 km length. A length of 10 km was settled upon as this allowed for concentration of efforts near the focal habitats and leks. Another consideration in selection of the 10-km transect length was that it could allow for direct comparison with a standard relative abundance index (birds per 10 km) that has been used in some other North American sage-grouse predator monitoring programs (Coates and Delehanty 2010). Transect length also considers that using several short rather than few long transects could help reduce bias and increase precision (Nomani et al. 2012).

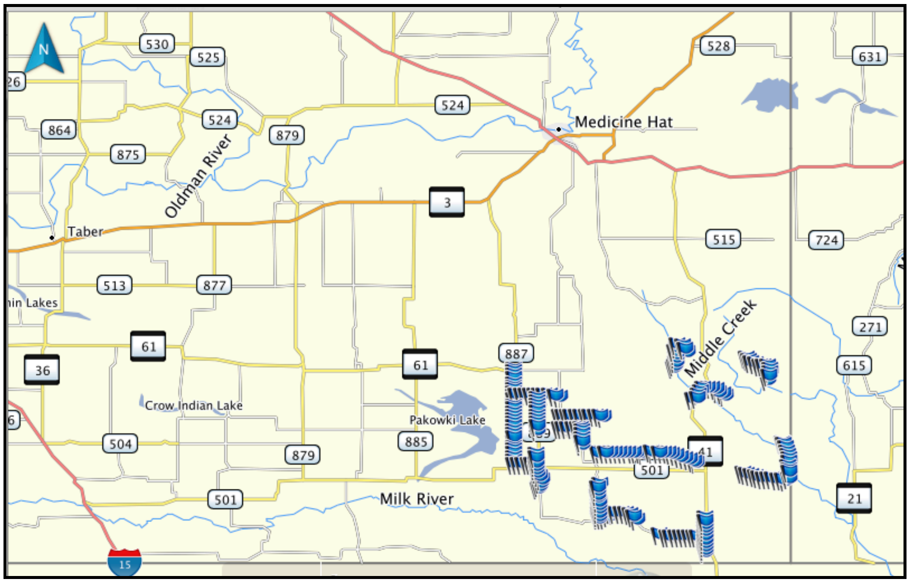

Figure 1: General location of Alberta greater sage-grouse avian predator transects

4.8. Time of Day for Surveys

Surveys for birds are generally carried out from the period 30 minutes before sunrise until mid to late morning (North American Breeding Bird Survey; Saunders 2001). For corvids, however, the time period for observing may be less restrictive. In Washington, Luginbuhl et al. (2001) found that there was no correlation between time of day and observations of corvids for surveys done between 0600 and 1400 hrs. In agricultural areas outside Davis, California, Moore and Switzer (1998) documented mid afternoon movements of American crows to certain fields where they exhibited pre-roosting aggregations. As a precautionary measure, the Alberta surveys have been designed to conclude before mid-afternoon to avoid the possibility that such a phenomenon occurs here. Seckel (2011) observed that common ravens in the Mount Ranier area of Washington were best detected on quiet mornings with little wind. This suggests the morning period may still be of greatest value for observing some corvids.

The Alberta sage-grouse avian predator surveys were scheduled from sunrise to early afternoon (approx. 0600 to 1400 during the early May survey period). This was selected to avoid the pre-dawn period of dim light, to capture the anticipated morning period of higher activity, and to avoid the possibility of experiencing either absences or low activity periods, or, alternatively, any pre-roosting aggregations that might occur in mid afternoon. Survey observations in 2013 showed an apparent slow-down of activity after 1300 leading to a change in protocol to stop surveying at 1300 hrs (see Discussion section).

4.9. Length of Observation Period

Many different observation period lengths have been used in avian point counts and specialized corvid surveys. Three-minute durations have commonly been used in breeding bird surveys and some corvid surveys (North American Breeding Bird Survey, Coates et al. 2007). Five-minute durations have been used for some bird surveys in Alberta and elsewhere (Saunders 2001). Longer observation periods of ten to 20 minutes have been used in some of the sage-grouse predator research projects (Howe 2012, Dinkins et al. 2012, Luginbuhl et al. 2001,Bui et al. 2012). A longer period may increase opportunity for detection at an observation point, but at a trade-off of reduced numbers of stops completed each day and increased possibility of double-counting birds. Given the mobile and wide-ranging habits of corvids, there was concern for an increased likelihood of double-counting if lengthy stops were to be used.

A three-minute observation period was selected for the Alberta sage-grouse avian predator survey. This allowed for adequate observation time while reducing potential for double counting. The time period also allowed for more transects to be competed each day thereby also reducing the likelihood of double counting on consecutive survey days.

4.10. Detection Procedures

The radius for each point sample was derived from an assumed effective distance of detection of 500 meters. This exceeds the usual 400-m observation distance for songbirds (Robbins et al. 1986) but is defensible on the premise the target species (common ravens, American crows, black-billed magpies) are large, active birds exhibiting frequent flight and loud calling behaviour. The resulting distance of 1000 m between stops also provided a good fit for derivation of the birds per 10 km index.

It was recognized that avian predators may, under some circumstances, be observed at distances of much greater than 500 m. The open terrain, noisy behaviour of corvids, territoriality and positive response to call-playback, and soaring characteristics of ravens and hawks all contribute to increased distance of observation. A procedure to record any avian predators observed within 1000 m was included.

Surveys in other areas of North America have often relied on passive observations during the observation period (Howe 2012, Dinkins et al. 2012, Bui et al. 2012). Luginbuhl et al. (2001) used a combination of periods of silence, crow calls and predator calls. The previous section identifies that the Alberta sage-grouse avian predator surveys are designed with a three-minute observation and listening period at each stop. The first minute entails observation and silent listening followed by broadcasting of electronic corvid and predator calls for the second minute, then silent listening for the third minute.

4.11. Sample Size and Data Analysis

For this survey, sample size could be influenced by length of transect, frequency of samples along each transect and number of transects. Considerations in determining sample size included the size of the project area, the amount of access within the project area, numbers of observations anticipated to occur, the desired statistical power in trend estimation, and logistical considerations such as financial and staff resources.

A decision was made to include 20 transects, all of equal length (10 km) and each containing 10 point samples per transect. One transect proved impassable and was subsequently dropped from the protocol. Transects were located in, or near to, sage-grouse critical habitat. Transects were positioned with the mid-point of each transect nearest to an adjacent lek.

Depending upon the nature of results collected over a series of annual surveys, trend analysis may be derived by linear regression *t*-test, route regression methods or other statistical tests (Hatfield et al. 1996, Sauer and Droege 1990). Determination of necessary sample size prior to a project is an educated guess due to many variables, but it is anticipated that provision of up to 190 data points per survey (19 transects with 10 points each), should allow for adequate statistical power in determination of trends. The use of multiple transects should allow for multiple observations of avian predators, even if they occur in low numbers. A review of recent year observations at nearby North American Breeding Bird Survey (BBS) routes shows totals of up to 32 American crows and 33 black-billed magpies on the 40-km surveys. This suggests adequate numbers should be found on multiple 10-km surveys to derive an index of relative abundance and to discern trends after a series of annual surveys. The exception may be common raven occurrences, which are much lower with just 1-3 birds per BBS route.

4.12. Experimental Control Area

Experimental controls can be used to provide parallel observations for verifying effects of population treatments (Garton et al. 2005). Providing surveys in a control area not subjected to sage-grouse predator management activities could help interpret whether observed trends over time are due to the management treatment or some other factor such as weather. A control sample, however, would increase the effort for the survey thereby increasing time and resources required. For that reason, specific experimental controls were not provided. Alternatively, if a surrogate control could be found then limited resources could be used elsewhere to meet sage-grouse recovery objectives.

A surrogate control was found in the presence nearby of several transects of the North American Breeding Bird Survey (BBS). These surveys could potentially be analyzed to discern trends in abundance of corvids and other avian predators outside the treatment area but nearby within the dry mixedgrass natural subregion. There are nine BBS routes near the project area including #1 Seven Persons, #2 Bow Island, #3 Milk River, #102 Sherbourne, #201 Thelma, #202 Etzikom, #206 Bowell, #301 Rush Lake, and #302 Legend (North American Breeding Bird Survey 2013). One additional BBS route, #101 Manyberries, overlaps into the project area. The BBS trends could be compared against trends derived after several years of application of this protocol to help with interpretation of predator management effectiveness. Through this, the BBS could serve as a surrogate experimental control measure. A difficulty exists, however, in that three (#1,102, 202) of the nine routes are currently “vacant” meaning there is no volunteer assigned to those surveys. Sage-grouse managers are encouraged to actively pursue volunteers to resume the annual BBS surveys on those routes.

5. HABITAT DATA AND ANTHROPOGENIC STRUCTURES

Sage-grouse avian predators are likely to be associated with some habitats more than others. A protocol was included to record habitat at each stop. Of particular importance is the need to discern native versus anthropogenic habitats and noting of any raised structures that could favour avian predator use of an area. It has been found that risk of sage-grouse nest and brood failure to predation increases with proximity to anthropogenic features on the landscape (Dzialak et al. 2011). Infrastructure associated with industrial developments also has potential to provide habitat for sage-grouse predators (Dzialak et al. 2011). Storage tanks, communication and transmission towers and buildings can provide nesting substrates for some avian predators. Utility poles may be used as perches by avian predators. This "subsidization" of predators can have severe impacts on prey species (Dzialak et al. 2011). Predation has been shown to be the primary driver of sage-grouse nest and brood failure and predation risk is greater in and around human-modified areas (Dzialak et al. 2011).

The Alberta sage-grouse avian predator survey was designed to include a protocol of recording anthropogenic structures as they occur on each sampling transect. This protocol will provide the opportunity to monitor the development or removal of these "predator subsidies" over subsequent years.

The data that was collected on habitat and anthropogenic structures was used to provide a habitat classification for each survey stop. The resulting habitat classes were used to derive species-habitat correlations. The following habitat classes were used in that analysis:

Habitat Class A: ≥50% Native Grass, >1 km from Anthropogenic Features, No Riparian.
Habitat Class B: ≥50% Native Grass, < 1 km from anthropogenic Features, No Riparian.
Habitat Class C: <50% Native Grass, >1 km from Anthropogenic Features, No Riparian.
Habitat Class D: <50% Native Grass, <1 km from Anthropogenic Features, No Riparian.
Habitat Class E: Riparian Present, >1 km from Anthropogenic Features.
Habitat Class F: Riparian Present, <1 km from Anthropogenic Features.

6. RESULTS

Transects were surveyed initially during the period March 27, 28, 29, & 30, 2013. This was the first time this survey was done and time was spent locating transects, classifying habitats, photographing and describing anthropogenic structures as well as surveying avian predators. It became evident during this survey that timing and conditions were not optimal for sampling of avian predators. In the central portion of the project area the landscape was partially snow-covered while elsewhere snow melt was underway with flooded fields and ditches running high with water. Some species such as great-horned owl and black-billed magpie were actively nesting and easily observed but there were also numerous occurrences of migratory species such as rough-legged hawk and bald eagle. American crows had been present for some time but encounters of several flocks of 20-40 birds exhibiting migratory flight patterns provided the realization that there are several "waves" of crow migration into Alberta. These observations contributed to a decision to redo the survey later in spring. The results of the March 27-20 survey were used for habitat classification and photo documentation of anthropogenic structures, but the bird survey data was no used.

A second survey was completed during the period May 14,15,16, 2013. The bird observations recorded on that survey are summarized, along with habitat classifications, in Appendix A. A photo-documentation file of habitat and anthropogenic features was produced and stored on DVD.

A total of 46 black-billed magpies, 67 American crows and 3 common ravens were observed on transects. When presented as an abundance index (#birds/10 km) this results in values of 2.42 black-billed magpies, 3.53 American crows and 0.16 common ravens per 10 km (Table 1).

Table 1: Total Number and Abundance Index Values for Target Species

Species	Total #	Abundance Index (#/10 km)
Black-billed Magpie	46	2.42
American Crow	67	3.53
Common Raven	3	0.16

6.1. Habitat Associations of Corvids

The survey included 19 transects with 190 stops. Stops were categorized into 5 habitat classes based upon habitat type and presence or absence of anthropogenic features, as follows:

A. 50% or greater native grassland, no riparian, no anthropogenic features within 1 km (75 stops);
B. 50% or greater native grassland, no riparian, anthropogenic features present within 1 km (74 stops);
C. Less than 50% native grassland, no riparian, no anthropogenic features within 1 km (0 stops);
D. Less than 50% native grassland, no riparian, anthropogenic features present within 1 km (4 stops);

E. Riparian habitat occurrence, no anthropogenic features within 1 km (16 stops);
F. Riparian habitat occurrence, anthropogenic features present within 1 km (21 stops).

Corvids showed very little use of unmodified native grasslands in the southern Alberta project area. Results of the survey showed that in Class A habitats (native grassland without anthropogenic features) the occurrence of both American crows and black-billed magpies was significantly less than expected when a chi square test was used (Table 2, Appendix D). Survey results showed a strong avoidance of these native grassland habitats by these species.

Table 2: Black-billed Magpie and American Crow Habitat Use as Shown by Chi Square Analysis.

Habitat Class	# Stops	Expected # Magpies	Observed # Magpies	Habitat Use
A	75	18	3	Avoided
B	74	18	12	As Available
C	0	0	0	NA
D	4	1	3	NA
E	16	4	5	As Available
F	21	5	22	Selected

Habitat Class	# Stops	Expected # Crows	Observed # Crows	Habitat Use
A	75	26	4	Avoided
B	74	26	14	As Available
C	0	0	0	NA
D	4	1	1	NA
E	16	6	16	Selected
F	21	7	32	Selected

Where anthropogenic structures are present in native grasslands, there was a higher abundance of crows and magpies. In the Class B habitats (native grassland with presence of anthropogenic features) there were greater numbers of magpies and crows observed than in Class A habitats. Application of a chi square test (Table 2, Appendix D) showed that occurrence of back-billed magpie and American crow was consistent with habitat availability. This shows increased suitability and use by these corvids in native grasslands where anthropogenic structures are present.

Presence of riparian habitat was expected to be a strong influence on habitat suitability for corvids. In Class E habitats (riparian without anthropogenic) the occurrence of American crow was significantly greater than expected, showing selection of these habitats by crows (Table 2, Appendix D). For black-billed magpie, the null hypothesis was not rejected, indicating use in accordance with availability. These results support the assumption that presence of riparian habitat provides habitat suitability for both species.

Riparian habitats in proximity to anthropogenic features had the strongest positive influence on use by both crows and magpies. In Class F habitats (riparian with presence of anthropogenic) the occurrence of both American crow and black-billed magpie was highest, showing extremely high selection of these habitats by both species. Occurrence was highest in riparian areas closely associated with farms, residences, and cattle corrals.

6.2. Value as a Baseline Survey

The primary goal of the 2013 survey was to provide a baseline for comparison purposes in future years. During the March survey there was uncertainty of the survey usefulness for this purpose, due to large concentrations of birds distributed in an unpredictable manner. The May survey, however, showed strong habitat correlations and birds exhibiting behaviour that indicated they were resident in the areas where they were observed. The crows and magpies were not migrating nor did they appear to be on wide-ranging flights. This observation along with the standardization of protocol should provide a repeatable survey useful for monitoring population trends in avian predators.

6.3. Other Species

There were only three observations of the common raven. Densities of this species appear to be so low in the project area that a very intensive effort would be needed to provide adequate numbers for analysis. In the event of population increases an upward trend should be noticeable in subsequent years. Based on anecdotal observations in the area, ravens tend to be associated with badland areas as well as anthropogenic structures.

A total of 12 ferruginous hawks were observed on the survey. This species is strongly associated with native grasslands, taking advantage of cliffs and lone trees for nest, but also readily adapts to using artificial pole nests.

Fifteen Swainson’s hawks and five northern harriers were observed on transects. Both occurred in a variety of habitats but Swainson’s hawks were more closely associated with farm yards and domestic trees.

Survey timing was not optimal for most grassland bird species; however there were sporadic observations of some, particularly Sprague’s pipit (*Anthus spragueii*). This species, as expected, was closely associated with native grasslands.

7. DISCUSSION AND MANAGEMENT IMPLICATIONS

The 2013 sage-grouse avian predator survey provided a baseline measure of populations for comparison with future surveys. Information was summarized as total numbers and in an abundance index, as number of corvids per 10 km of transect length. The abundance index may be useful in monitoring trends and relating them to levels of sage-grouse predation. Coates and Delehanty (2010) used this approach in Nevada and found that an increase of one raven per 10 km resulted in a 26% increase in the odds of a raven predation.

Timing of surveys was most effective during May, after corvid species have completed their migration. One possible drawback is that this is at the end of the nesting/rearing period for great-horned owls and hence their presence may be underestimated.

The survey showed strong habitat correlations of crows and magpies with both riparian habitats and anthropogenic features. These correlations provide valuable Alberta-based information that can be used to assist with management decisions.

Crows and magpies were found to be absent from almost all areas of native grassland without anthropogenic structures, but present with regularity in native grassland with anthropogenic structures. The native grasslands should be the highest priority areas for removal of anthropogenic structures as these structures effectively provide predator subsidies in sage-grouse critical habitat.

The strong association of avian predators with anthropogenic structures in native grasslands, where they would otherwise not occur, also provides strong rationale for carrying out predator management in these habitats. Predator management in these habitats could have a positive impact on sage-grouse survival and production.

Riparian areas provide habitat for crows and magpies. The addition of anthropogenic structures greatly increases use of riparian areas by corvids. Where possible and feasible, particularly when in sage-grouse critical habitat, anthropogenic structures should be removed in riparian habitats.

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APPENDIX A: Greater Sage-grouse Avian Predator Survey 2013 Data

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
1-1	12 U 513548 5478350	B	Village							
1-2	12 U 513553 5477400	B	Residence & Domestic Trees							
1-3	12 U 513555 5476377	D	Residence & Domestic Trees							
1-4	12 U 513557 5475116	B	Residence & Domestic Trees							
1-5	12 U 513561 5474103	D	Residence & Domestic Trees							
1-6	12 U 513565 5473497	B	Industrial							
1-7	12 U 513555 5472686	B	Industrial							
1-8	12 U 513570 5471573	A	Dunes, Native Trees		2					
1-9	12 U 513570 5470715	A	Dunes, Native Trees	1	1					
1-10	12 U 513582 5469450	A	Dunes, Native Trees							
2-1	12 U 514065 5471869	A	Dunes, Native Trees		1					
2-2	12 U 515194 5471887	A	Dunes, Native Trees							

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
2-3	12 U 516063 5471881	B	Abandoned Buildings				1			
2-4	12 U 517237 5471889	A	Native Grassland							
2-5	12 U 518141 5471886	B	Residence & Domestic Trees							
2-6	12 U 519107 5471890	A	Native Grassland							
2-7	12 U 520075 5471891	B	Abandoned Buildings, Domestic Trees							
2-8	12 U 521272 5471891	B	Village		2					
2-9	12 U 522482 5471629	D	Village	3	1				1	
2-10	12 U 523319 5471325	F	Village							
3-1	12 U 513576 5468330	B	Domestic Trees						2	
3-2	12 U 513578 5467305	B	Domestic Tree				1		1	
3-3	12 U 513589 5466206	D	Residence & Domestic Trees							
3-4	12 U 513582 5465461	F	Residence & Domestic Trees	1						
3-5	12 U 513586 5464397	A	Native Grassland	2						

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
3-6	12 U 513594 5463636	B	Abandoned Buildings	2						
3-7	12 U 513589 5462549	B	Domestic Trees							
3-8	12 U 513591 5461412	B	Domestic Trees							
3-9	12 U 513592 5460521	B	Industrial							
3-10	12 U 513593 5459551	B	Dunes & Cultivation		6					
4-1	12 U 513592 5457186	F	Creek, Residence, Domestic Trees	1(NEST)	2					
4-2	12 U 513594 5456281	B	Domestic Trees							
4-3	12 U 513596 5455260	B	Domestic Trees							
4-4	12 U 513598 5454343	B	Domestic Trees	1(NEST)			1 (NEST)			
4-5	12 U 513601 5453489	B	Domestic Trees						1 (NEST)	
4-6	12 U 514590 5453278	B	Domestic Trees, Residence		3					
4-7	12 U 515503 5453282	B	Residence & Domestic Trees							

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
4-8	12 U 516624 5453286	B	Domestic Trees							1 UPSA
4-9	12 U 517441 5453293	B	Domestic Trees	2(1 NEST)						1 SPPI
4-10	12 U 518479 5453296	A	Native Grassland and Sagebrush							
5-1	12 U 519171 5447500	A	Native Grassland							
5-2	12 U 519474 5448363	A	Native Grassland & Badlands						1	2 COYO
5-3	12 U 519525 5449243	A	Native Grassland & Badlands							
5-4	12 U 519074 5450118	A	Native Grassland							
5-5	12 U 518538 5451009	A	Native Grassland							
5-6	12 U 518501 5451873	A	Native Grassland							
5-7	12 U 518497 5452908	A	Native Grassland							
5-8	12 U 518492 5453846	E	Native Trees and Shrubs							
5-9	12 U 518482 5455356	A	Native Grassland							
5-10	12 U 518485 5456179	A	Native Grassland							

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
6-1	12 U 518450 5471240	B	Abandoned Buildings, Domestic Trees							
6-2	12 U 518452 5470285	A	Native Grassland							
6-3	12 U 518456 5469362	B	Native Grassland & Hawk Pole							
6-4	12 U 518464 5468316	A	Native Grassland				1 (nest)			1 SPPI
6-5	12 U 518463 5467364	B	Lone Domestic Tree							
6-6	12 U 518465 5466456	B	Native Grassland, Powerline							1 SPPI
6-7	12 U 518473 5465446	B	Native Grassland, Powerline							1 SPPI, 2LBCU
6-8	12 U 518477 5464416	B	Native Grassland, Powerline		1					1 SPPI
6-9	12 U 518478 5463598	F	Powerline; Native Trees, Residence	1	3					
6-10	12 U 518481 5462527	F	Powerline; Native Trees, Residence		2					
7-1	12 U 523980 5466247	A	Native Grassland							1 SPPI
7-2	12 U 524971 5466250	A	Native Grassland							
7-3	12 U 525858 5466255	B	Domestic Tree, Dugout	1 (nest)						

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
7-4	12 U 526894 5466259	B	Domestic Trees, Cattle Corral	1						
7-5	12 U 527911 5466265	B	Domestic Trees, Abandoned Buildings							
7-6	12 U 529126 5466271	B	Corral					1		
7-7	12 U 529893 5466275	B	Powerline, Industrial							
7-8	12 U 530895 5466279	B	Powerline, Industrial							
7-9	12 U 531888 5466282	F	Powerline, Industrial, Native Shrubs	1						
7-10	12 U 532796 5466157	B	powerline, industrial, Domestic Trees	1	2				1 (nest)	
8-1	12 U 523985 5463010	A	Native Grassland						1	
8-2	12 U 525081 5463014	B	Domestic Trees, Granaries							2 COYO
8-3	12 U 526139 5463019	B	Domestic Trees, Granaries	1			1			1 SPPI
8-4	12 U 527094 5463028	B	Domestic Trees, Granaries	1					1	1 COYO
8-5	12 U 527939 5463028	B	Domestic Trees						1	
8-6	12 U 528252 5462357	A	Native Grassland							1 SPPI

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
8-7	12 U 528256 5461552	B	Domestic Trees, Barn	1					1	1 STGR
8-8	12 U 528265 5460269	B	Domestic Trees, Barn							1 UPSA, 1 SPPI
8-9	12 U 528268 5459380	A	Native Grassland						1	1 UPSA
8-10	12 U 528271 5458470	F	Domestic Trees, Residence	6	4					1 LOSH
9-1	12 U 531929 5439430	B	Native Grassland, Powerline							1 SPPI
9-2	12 U 531923 5440348	B	Native Grassland, Powerline			1				
9-3	12 U 531915 5441510	B	Native Grassland, Powerline							
9-4	12 U 531911 5442332	B	Native Grassland, Powerline							
9-5	12 U 531903 5443275	B	Native Grassland, Powerline							1 SPPI
9-6	12 U 531583 5444414	B	Native Grassland, Powerline							
9-7	12 U 531567 5445010	B	Powerline, Domestic Tree							
9-8	12 U 531532 5446303	B	Powerline, Residence, Domestic Trees							1 SPPI
9-9	12 U 531702 5447149	B	Native Grassland, Badlands, Powerline							

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
9-10	12 U 531949 5448064	B	Native Grassland, Powerline							
10-1	12 U 532490 5438889	B	Domestic Trees							1 SPPI
10-2	12 U 533369 5438847	B	Domestic Trees			1			1 (nest)	1 SPPI
10-3	12 U 534041 5439498	B	Domestic Trees							1 LOSH
10-4	12 U 534603 5440329	B	Domestic Trees							
10-5	12 U 535583 5440405	B	Domestic Trees							
10-6	12 U 536716 5440412	B	Domestic Trees							1 GOEA
10-7	12 U 537654 5440413	A	Native Grassland							
10-8	12 U 538587 5440042	B	Domestic Trees							2 LOSH, 1 SPPI
10-9	12 U 539263 5439415	B	Domestic Trees							1 SPPI
10-10	12 U 540038 5438706	B	Domestic Trees	2						
11-1	12 U 545368 5434241	A	Native Grassland							1 SPPI
11-2	12 U 546477 5434010	A	Native Grassland							

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
11-3	12 U 547389 5434019	A	Native Grassland							
11-4	12 U 548410 5434022	A	Native Grassland							1 SPPI
11-5	12 U 549353 5434033	A	Native Grassland							1 SPPI
11-6	12 U 550467 5434042	A	Native Grassland							2 SPPI
11-7	12 U 551375 5434053	A	Native Grassland							2 SPPI
11-8	12 U 552321 5434062	A	Native Grassland							1 SPPI
11-9	12 U 553151 5434068	A	Native Grassland							1 SPPI
11-10	12 U 554202 5434076	A	Native Grassland							
12-1	12 U 554728 5430605	B	Powerline, Native Grassland							
12-2	12 U 554712 5431611	B	Powerline, Native Grassland							
12-3	12 U 554701 5432471	B	Powerline, Native Grassland							
12-4	12 U 554687 5433442	B	Powerline, Native Grassland							
12-5	12 U 554676 5434384	F	Powerline, Native Trees							

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
12-6	12 U 554660 5435552	B	Powerline, Domestic Trees							
12-7	12 U 554648 5436519	B	Powerline, Domestic Tree, Hawk Pole							
12-8	12 U 554636 5437458	B	Powerline, Native Grassland, Corral							
12-9	12 U 554624 5438435	A	Native Grassland							
12-10	12 U 554617 5439328	A	Native Grassland							1 SPPI
14-1	12 U 540898 5456475	A	Native Grassland							1 SPPI
14-2	12 U 539973 5456628	A	Native Grassland							
14-3	12 U 539107 5456621	A	Native Grassland							
14-4	12 U 538087 5456615	A	Native Grassland							1 SPPI
14-5	12 U 537143 5456610	A	Native Grassland							1 SPPI
14-6	12 U 536115 5456603	A	Native Grassland							
14-7	12 U 535093 5456596	A	Native Grassland							
14-8	12 U 534074 5456588	A	Native Grassland							1 SPPI

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
14-9	12 U 533129 5456584	A	Native Grassland							1 SPPI
14-10	12 U 532280 5456582	B	Domestic Trees, Residence							
15-1	12 U 552066 5454299	A	Native Grassland							
15-2	12 U 551077 5454719	A	Native Grassland							3 PRON
15-3	12 U 550310 5455051	A	Native Grassland							
15-4	12 U 549297 5455487	A	Native Grassland							
15-5	12 U 548418 5455866	A	Native Grassland							1 SPPI
15-6	12 U 547455 5456284	B	Aspen, Abandoned Railroad							1 SPPI
15-7	12 U 546586 5456653	B	Aspen, Abandoned Railroad				1 (nest)			
15-8	12 U 545637 5456673	B	Aspen, Abandoned Railroad							1 SPPI 1 LBCU 4PRON
15-9	12 U 544585 5456482	E	Creek							1 BASP
15-10	12 U 543588 5456697	E	Creek							1 SPPI

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
16-1	12 U 563441 5451088	A	Native Grassland							
16-2	12 U 564332 5450842	A	Native Grassland							
16-3	12 U 565461 5450483	A	Native Grassland							1 SPPI
16-4	12 U 566192 5450203	A	Native Grassland							1 SPPI
16-5	12 U 566959 5449995	A	Native Grassland							
16-6	12 U 568075 5450026	E	Creek, Native Grassland							
16-7	12 U 569021 5449925	A	Native Grassland				1			
16-8	12 U 570203 5449740	A	Native Grassland							
16-9	12 U 571009 5449611	A	Native Grassland				1			
16-10	12 U 571801 5449483	A	Native Grassland							
17-1	12 U 571273 5459117	E	Creek, Cattle	2	2					
17-2	12 U 571652 5458274	E	Creek, Cattle							
17-3	12 U 572099 5457284	E	Creek, Cattle		2					

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
17-4	12 U 572247 5456255	F	Creek, Residence, Domestic Trees							
17-5	12 U 572392 5455419	F	Domestic Trees, Reservoir	2						waterfowl
17-6	12 U 572403 5454501	F	Domestic Trees				1 (nest)			4 RBGU
17-7	12 U 572397 5453338	F	Domestic Trees	2						
17-8	12 U 572430 5452479	F	Domestic Trees	1			1			20 AMPE
17-9	12 U 572440 5451729	F	Nest Pole		2					
17-10	12 U 572454 5450529	A	Native Grassland				1			
18-1	12 U 563506 5481565	A	Native Grassland							
18-2	12 U 564144 5481034	A	Native Grassland							1 SPPI
18-3	12 U 565051 5480638	A	Native Grassland					1		
18-4	12 U 566032 5480246	E	Pond				1	2		
18-5	12 U 566699 5480319	A	Native Grassland							
18-6	12 U 567599 5480255	A	Native Grassland							

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
18-7	12 U 568033 5479418	A	Native Grassland							1 MAGO
18-8	12 U 568193 5478345	E	Pond							
18-9	12 U 568004 5477517	A	Native Grassland					1		
18-10	12 U 567785 5476416	A	Native Grassland							
19-1	12 U 558075 5472438	B	Residence & Domestic Trees							
19-2	12 U 557325 5472923	A	Native Grassland							1 SPPI
19-3	12 U 556733 5473633	A	Native Grassland							
19-4	12 U 555886 5473914	E	Creek	1	3					
19-5	12 U 554884 5474181	E	Creek							
19-6	12 U 553921 5474165	E	Creek	1	1					
19-7	12 U 553346 5473164	E	Creek							
19-8	12 U 552965 5472217	A	Native Grassland							
19-9	12 U 552601 5471457	A	Native Grassland							

Stop #	Location	Habitat*	Feature	BBMA	AMCR	CORA	FEHA	NOHA	SWHA	OTHER
19-10	12 U 551812 5470962	A	Native Grassland							
20-1	12 U 547745 5480094	F	Riparian, Native Grassland							1 LBCU
20-2	12 U 548008 5480979	E	Riparian, Native Grassland							1 LBCU
20-3	12 U 548144 5482111	F	Buildings, Riparian							1 LBCU
20-4	12 U 548036 5483044	F	Buildings, Riparian	1	1					1 LBCU, STGR
20-5	12 U 547911 5484003	E	Riparian, Native Grassland		5					
20-6	12 U 548166 5484853	E	Riparian, Native Grassland		3	1				
20-7	12 U 548315 5485545	F	Corrals, Riparian		1					
20-8	12 U 549531 5485236	F	Residence & Domestic Trees	2	2					1 RTHA
20-9	12 U 549875 5484356	F	Riparian Trees and Shrubs, Cattle	4	7					
20-10	12 U 550489 5483660	F	Riparian Trees and Shrubs, Cattle	1	8				2	

Habitat Class A: ≥50% Native Grass, >1 km from Anthropogenic Features, No Riparian.
Habitat Class B: ≥50% Native Grass, < 1 km from anthropogenic Features, No Riparian.
Habitat Class C: <50% Native Grass, >1 km from Anthropogenic Features, No Riparian.
Habitat Class D: <50% Native Grass, <1 km from Anthropogenic Features, No Riparian.
Habitat Class E: Riparian Present, >1 km from Anthropogenic Features.
Habitat Class F: Riparian Present, <1 km from Anthropogenic Features.

APPENDIX B: Instructions for Conducting Sage-grouse Predator Surveys

LOCATION

Refer to your DESCRIPTION OF TRANSECT. It includes a map as well as a geo-referenced start point, junctions and other orienting features, and where the route ends. The description and accompanying map should be used to help you stay on course.

PRE-SURVEY FAMILIARIZATION AND HABITAT DATA COLLECTION

Drive your survey transect in advance. This should be done the day before the survey outside the survey protocol period (generally in the afternoon or evening). You may wish to record your habitat data at this time, or it can be done during the survey. In future years this information will be used as a benchmark to detect and record any modifications in habitat and land use. This data will also help to interpret habitat use by target species. As you drive your route this first time, at the first 500-m point of the transect, and every 1000 m thereafter, enter a waypoint on your GPS unit. Manually record the GPS coordinates onto the data sheet. In subsequent years a GPS waypoint file will be available. Record an estimated percentage for each broad habitat type within a circle of 50-m radius. If the habitat does not fit one of the broad habitat types provided on the data sheet then record as "other" and describe it in a few words. As you drive your route look for significant habitat/anthropogenic features that could be important to sage-grouse predators. At each stop, describe these features on the Anthropogenic/Habitat Features data sheet. From each stop describe distance in meters and compass direction (0 to 360 degrees) to the feature. Photograph the feature and note a photo descriptor number on the Anthropogenic/Habitat Features data sheet.

SAGE-GROUSE PREDATOR SURVEY

Timing: Be at the start of your route and ready to start collecting data by sunrise (sunrise is approx. 0600 on May 1). Continue to survey the route until you have completed all 10 km (10 stops). It will take an hour or more to complete. Surveys should be completed by 1300 hrs. You may have time to complete five to six surveys per day.
Weather: Do not conduct the survey in inclement weather for observing, as represented by sustained high winds (>25 km/hr), steady rainfall or snowstorm conditions.
Surveying: At the start of the survey set your trip odometer to 0 and drive to your first GPS point at 500 m. This will be your first observation point. Subsequent observation points will occur every 1000 m. At each stop place the game caller on the roof or hood of the truck with speakers activated. Use a three-minute timer. Observe and listen for one minute, play the series of corvid and predator calls for the second minute while observing, then observe and listen for the third minute. Tally onto the data sheet the number of observations for each target species seen and heard during the 3-minute count period at each stop. Binoculars will be needed and a spotting scope should be available for distant observations (e.g., to check if a hawk pole is occupied). Take particular care to avoid double counting birds on adjacent stops.
Target Species: The survey is designed for observation of aerial predators, particularly corvids. However, all predators and potential predators of sage-grouse should be observed and recorded. Target species are listed below:

- Corvids, including American crow, common raven, black-billed magpie;

- Owls, including great-horned owl, short-eared owl, long-eared owl;
- Eagles: golden eagle, bald eagle;
- Buteos: Swainsons hawk, ferruginous hawk, red-tailed hawk, rough-legged hawk;
- Accipiters: Cooper's hawk, sharp-shinned hawk;
- Loggerhead shrike;
- Mammalian predators/potential predators: coyote, red fox, swift fox, bobcat, American badger, striped skunk, raccoon, long-tailed weasel.

Additional Species: The survey timing and protocol is not optimal for most other species; however, some species should be recorded when encountered. These include priority species such as those listed as provincial/federal Endangered, Threatened, and Special Concern. Examples include burrowing owl, upland sandpiper, loggerhead shrike Sprague's pipit, chestnut-collared longspur, Baird's sparrow, and others.

SIGNIFICANT HABITAT AND ANTHROPOGENIC FEATURES

Significant habitat features and anthropogenic structures need to be recorded. These are structural components of the landscape that are likely to support predator populations or enhance their use of the area. Descriptions and locations of these features should be documented through categorization, geo-referencing and photo-documentation, as described below:

a) Categorize as: *Anthropogenic* (human-caused) or *Natural* (naturally-occurring) features on the landscape.

b) Describe as one of these features: *Tree/Trees* (single, linear shelterbelt, grove), *Shrubs* (linear or groves), *Transmission Line* (large towers), *Distribution Line* (single poles), *Farm Buildings* (occupied or abandoned), *Fences, Raptor Nest Poles* (in use, recently used, or not used), *Industrial Structures* (e.g., oil and gas wells, buildings), *Agricultural Structures* (e.g., irrigation pivots, windmills), *Other Tall Structures* (e.g., transmission towers, wind turbines). *Other Potential Attractants* (e.g., garbage disposal areas, livestock carcass dumps, road-killed wildlife).

APPENDIX C: Data Sheets for Sage-grouse Predator Surveys

Sage Grouse Predator Survey *Transect #* ______

Date:______________

Weather Information:

Calm Light breeze (B1-2) Mod. breeze (B3-4) Windy (B5+)

Sunny Partially overcast Overcast

Temperature ____C

Light Rain Light Snow Other: _____________

STOP	Easting	Habitat %					Species (Circle if >500m)				Comments
	Northing	Ng	Tp	C	R	Other	BBMA	AMCR	CORA	Other	
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

Sage Grouse Predator Anthropogenic/Habitat Feature Form
Route # ______

Your Location (Stop # or UTM)	Direction to	Distance to	Habitat or Anthropogenic Feature	Closest Stop	Photo	Comments

APPENDIX D: Chi Square Test for Habitat Correlations

Chi-square is a statistical test used to compare observed data with expected data according to a specific hypothesis. It measures "goodness to fit" between the observed and expected and helps to interpret whether the differences between observed and expected are the result of chance or due to other factors. The formula for calculating chi-square (χ^2) is: $\chi^2 = (o-e)^2/e$. For this project, the chi-square test was used to evaluate the observed vs. expected number of corvid (crow and magpie) observations in each habitat class, with the “expected” category being provided by the proportion of the sample area in each habitat class. Applying this, the expected proportion of observations in class A habitat would be 75/190 = 0.394; Class B = 0.389; Class C = 0; Class D = 0.021; Class E = 0.084; and Class F = 0.110. Applying these proportions to the total numbers of magpies (46) and crows (67) observed in the 2013 survey, the expected and observed results are provided below:

Black-billed Magpie: Class A Expected=18 Observed=3; Class B Expected=18 Observed=12; Class D Expected=1 Observed=3; Class E Expected=6, Observed=5; Class F Expected=5 Observed=22.

American Crow: Class A Expected=26 Observed=4; Class B Expected=26 Observed=14; Class D Expected=1 Observed=1; Class E Expected=6 Observed=16; Class F Expected=7 Observed=32.

For this test the null hypothesis is that the observations of corvids (crows and magpies) were apportioned to habitat classes as expected by the proportional availability of each of those habitat classes. Acceptance of the null hypothesis would be indicated by no significant difference between observed and expected result. Chi square should not be calculated if the expected number is less than 5, so in this project that means results for Class D must be thrown out.

When calculated using the formula, for black-billed magpie (BBMA) there is a derived Class A chi square value of 18.6. The p value is $p<0.001$, therefore rejecting the null hypothesis and providing a highly significant probability that some factor other than chance is operating for the deviation to be so great. There is less than 0.1% chance that this deviation is due to chance alone, and therefore other factors must be involved. For BBMA there is a Class B chi square value of 5.54. $P<0.20$, a non-significant p value which does not reject null hypothesis. Class D is not calculable (less than 5 expected). For BBMA Class E shows a chi square value of 0.25, a non-significant p value which does not reject null hypothesis. For BBMA Class F there is a chi square value of 57.8. The p value is $p<0.001$ therefore rejecting the null hypothesis and providing a significant probability that some factor other than chance is operating for the deviation to be so great. There is less than 0.1% chance that this deviation is due to chance alone, and therefore other factors must be involved.

For American crow (AMCR) there is a derived Class A chi square value of 10.9. The p value is $p<0.05$, therefore rejecting the null hypothesis and providing a significant probability that some factor other than chance is operating for the deviation to be so great. There is less than 5% chance that this deviation is due to chance alone, and therefore other factors must be involved. For AMCR there is a Class B chi square value of 0.88. $P<0.950$, a non-significant p value which does not reject the null hypothesis. Class D is not calculable (less than 5 expected). For AMCR Class E shows a chi square value of 36. The p value is $p<0.001$ therefore rejecting the null hypothesis and providing a significant probability that some factor other than chance is operating for the deviation to be so great. There is less than 0.1% chance that this deviation is due to chance alone, and therefore other factors must be involved. For AMCR the Class F chi square value is 145.8. The p value is $p<0.001$ therefore rejecting the null hypothesis and providing a significant probability that some factor other than chance is operating for the deviation to be so great. There is less than 0.1% chance that this deviation is due to chance alone, and therefore other factors must be involved.

Interpretation of the chi square tests:

- In Class A habitats (native grassland without anthropogenic features) the occurrence of both crows and magpies is significantly less than expected. Therefore these habitats may be interpreted as being avoided by these corvids and generally unsuitable for them.
- In Class B habitats (native grassland with presence of anthropogenic features) there were greater numbers of magpies and crows observed than in Class A habitats. The chi square test showed that the null hypothesis was not rejected, in other words, occurrence of corvids (magpies and crows) is consistent with habitat availability. This indicates a higher corvid suitability of Class B habitats over Class A habitats.
- There were no samples in Class C habitats.
- The number of sites in Class D habitats was too low for analysis.
- In Class E habitats (riparian without anthropogenic) the occurrence of crows was significantly greater than expected, therefore showing selection of these habitats by crows. For magpies the null hypothesis could not be rejected, thereby indicating use in accordance with availability, but still an indicator of habitat suitability.
- In Class F habitats (riparian with presence of anthropogenic) the occurrence of both crows and magpies was highest, showing highly significant rejection of the null hypothesis, indicating extremely high selection of these habitats by both magpies and crows.
- Numbers of common raven observed were too low to allow for habitat correlation analysis