

Fall 2018 Golden Eagle Migration Survey Big Belt Mountains, Montana



(Photo by Amy Seaman)

Report prepared by:

Amy Seaman, Montana Audubon

Report submitted to:

U.S. Forest Service, Helena-Lewis & Clark National Forest

ATTN: Denise Pengeroth, Forest Biologist

3425 Skyway Drive, Helena, MT 59602

March 2019

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For the Period: January 01, 2018 – December 21, 2018

Report prepared by:

Amy Seaman

Counts conducted by:

Amy Seaman and Volunteers

Project coordinated by:

GEMS Committee

Project Coordinator: Amy Seaman, Montana Audubon

Montana Audubon, P.O. Box 595, Helena, MT 59624-0001

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Introduction

The biannual migration of diurnal North American raptors, between their breeding and wintering grounds, is an excellent time for observers and researchers to quantify long-term trends in raptor species populations over time. For some species, even year-to-year demographic changes can be monitored. Typically, the best sites for monitoring raptors are along specific geographic features that concentrate individual birds such as north-south oriented mountain ridges or coastlines, and areas with optimal migratory conditions including strong thermals and mountain-driven updrafts. Formations like these enable the establishment of long-term, standardized count sites that contribute valuable migratory raptor population trend data in a cost-effective and repeatable manner (Zalles and Bildstein 2000, Farmer et al. 2007). This type of monitoring data is fundamental to understanding overall wildlife habitat and ecosystem health, as diurnal raptor populations are key biological indicators of overall wildlife habitat health (Bildstein 2001).

The Big Belt Mountains were first recognized as a significant Golden Eagle migration flyway by Missoula-based Raptor View Research Institute (RVRI) in 2007. Exploratory migration counts were conducted by Steve Hoffman, founder of HawkWatch International and former Executive Director of Montana Audubon, in October of 2014. On 11 October 2014, Hoffman, Dan Ellison and Jane Fournier documented an incredible 284 migrating Golden Eagles in 6.75 hours of observation. Additional counts that autumn produced Golden Eagle numbers consistently higher than the long-term monitoring site in the Bridger Mountains to the south. With the intent of capturing data for migrating raptors that could not be tallied in the Bridgers (data from migrating Golden Eagles equipped with satellite transmitters (by RVRI) shows that a significant number of migrant Golden Eagles, after traversing the length of the Big Belts, redirected their flight path eastward to the Crazy Mountains, avoiding the Bridger Mountains), and to better understand long-term trends in Golden Eagle populations along the Rocky Mountain Flyway, standardized counts began in the Big Belts during the fall of 2015. Golden Eagle monitoring at this site is especially necessary, because current data suggests long-term declines in North America beginning in the late 1990's (Smith et al. 2008, Sherrington 2017a & b). The Bridger Mountains, located approximately 60 miles south-southeast of the Big Belts (near Bozeman), is a historically significant site for counting migrant Golden Eagles. Golden Eagle numbers counted along this flyway have declined by 30%-40% (Smith et al. 2008, Davis et al. 2017) since standardized scientific counts began in 1992. The Big Belts have also proved an active migration route for many other raptors; remarkably, on 23 September, 2015, all 17 raptor species were recorded by observers. Data such as this may never have been documented before at any hawk watch site in western North America.

In fall 2015, Bret Davis and Ronan Dugan conducted the first standardized raptor migration count in the Big Belts from 15 September - 3 November (Davis & Hoffman 2016). Davis and Dugan camped at Duck Creek Pass and conducted daily migration surveys (weather permitting). Their effort produced astonishing results: 2,630 Golden Eagles were recorded in 352.8 hours observing, yielding one of the highest Golden Eagle passage rates known in North America (Yates et al. 2001, McIntyre and Lewis 2016, Grayum et al. 2017). In fall 2016, Ronan Dugan returned as a primary observer and was joined by Jeff Grayum. Surveys began 15 days earlier than in 2015, on 1 September, and ended on 5 November. The 2016 season was a collaborative effort among four

entities: Montana Audubon, Last Chance Audubon Society, Montana Fish, Wildlife, & Parks, and the U.S. Forest Service (Helena-Lewis & Clark National Forest), with each organization contributing unique and important roles. In 2016, the survey effort became collectively known as GEMS for Golden Eagle Migration Survey. Observers in 2016 spent 443.4 hours observing a total of 4,389 migratory raptors. The survey continued in 2017 with Jeff Grayum as a primary observer along with Hilary Turner. Observers again camped at Duck Creek Pass in 2017, and for the first time had access to a canvas wall tent and wood stove. Daily migration surveys were conducted 15 September – 31 October when storms cut surveys short. In 2017 a total of 295 hours of observing yielded 2,929 migrating raptors of 16 species (Hoffman & Davis 2017).

Surveys conducted in fall of 2018 were by primary observer Amy Seaman, Montana Audubon Conservation Program Manager, primary observers Shaun Highland and Erin Reather from the U.S Forest Service, and volunteers as possible (see Appendix B for a complete history of official observers for the GEMS project). In 2018 the GEMS partnership was made up of Montana Audubon, Montana Fish, Wildlife & Parks, and the U.S. Forest Service (Helena-Lewis & Clark National Forest). During surveys each fall from 2016 – 2018, Forest Service employees, provided ~2 surveys per week, contributing many valuable observation hours to the project. A total of 185.8 observation hours were recorded.

The primary objectives of this long-term study are to:

1. Annually quantify numbers and movement patterns of all diurnal raptor species, especially Golden Eagles, as they pass through the Big Belt Mountains, primarily to assess long-term population trends.
2. Determine the population demographics of Golden Eagles using the Big Belt flyway.
3. Collect daily site-based weather data to evaluate the migrants' behavioral responses to various weather patterns and how weather factors may influence our counts.
4. Engage local communities by developing public education opportunities to share the science and amazing spectacle of the fall raptor migration in the Big Belts.

Study Site

The Big Belts is a 75-mile long, northwest-southeast trending ridgeline managed by the Helena – Lewis and Clark National Forest in west-central Montana. The observation site is part of a network of ten migration survey sites in western Montana north through Alberta (Site G, Fig. 1). The range is bordered to the west by Canyon Ferry Lake, a 35,181-acre artificial reservoir created by the damming of the Upper Missouri River. To the east of the Big Belts lies Shields Valley and farther east is another string of northwest-southeast trending mountain ranges. Following the Big Belt Mountains toward the south-southeast leads to the Bridger Mountains, where many of the raptors migrating through the Big Belt Mountains likely pass. (Site I, Fig.1).

Strong southwesterly winds typically prevail across the crest of the Big Belts. These consistent winds, combined with the Big Belts' steep west-facing slopes, generate powerful orographic lift, providing ideal flying conditions for migrating raptors. The 'lake-effect' of Canyon Ferry Reservoir may enhance the consistency and speed of these westerly winds over the Big Belts. These factors, along with the prominent "leading line" created by the Rocky Mountain Front (that

extends to the north well into Canada) make the southern end of the Big Belts a profoundly significant concentration point for migrating raptors in autumn.

During fall 2018, two observation sites were utilized on the west slope of the Big Belts (Fig. 2). The primary lookout since the project's inception (including in 2018) is referred to herein as 'Radio Tower West Slope' (RTWS). This site is located along the ridgeline, 1.4 miles south of Duck Creek Pass (N = 46.476962 degrees, W = -111.256572 degrees). It is approximately 200m downslope from the radio communications towers, at an elevation of 8180 feet. In 2015, this site was referred to as "Far Down Hill" upon its establishment as the primary site. This lookout allows exceptionally close views of a relatively high percentage of the migrating raptors, allowing observers to accurately determine species, age and/or sex for a remarkably high proportion of the passing migrants. Access to the observation site from Duck Creek Pass is via a steep, rocky road suitable only for 4-wheel drive, high-clearance vehicles. (Visitors are encouraged to park at Duck Creek Pass and hike 1.4 miles and 900 feet in elevation gain to the observation site.)

When fog and low cloud cover dramatically reduced visibility at the primary site, the observers conducted the official count from a lower elevation, referred to herein as 'Saddle Knoll' (SK). SK's location is 0.6km north-northwest of Vista Point, at an approximate elevation of 7550 feet (N = 46.502518 degrees, W = -111.273463 degrees). Vista Point is 2.6km north of RTWS. This site was also used in 2016 and 2015, however it is on private land and used sparingly. In 2018 it was used because observers had to drive to the site each day. In 2018 for the first year, when extreme weather prevented counts from being conducted at either the primary and secondary sites the observers did not conduct counts. In past survey years, a lower elevation site along Duck Creek Road, herein referred to as 'Lower Duck Creek Rd' (LDCR). This observation site is on private land (used with landowner permission), located on a grassy saddle west of Duck Creek Pass at an elevation of approximately 6000 feet. This site is mostly suited for detecting only large raptors, due to its considerable distance from the ridgetop (and primary migratory flight path). LDCR was also used sparingly in 2016.

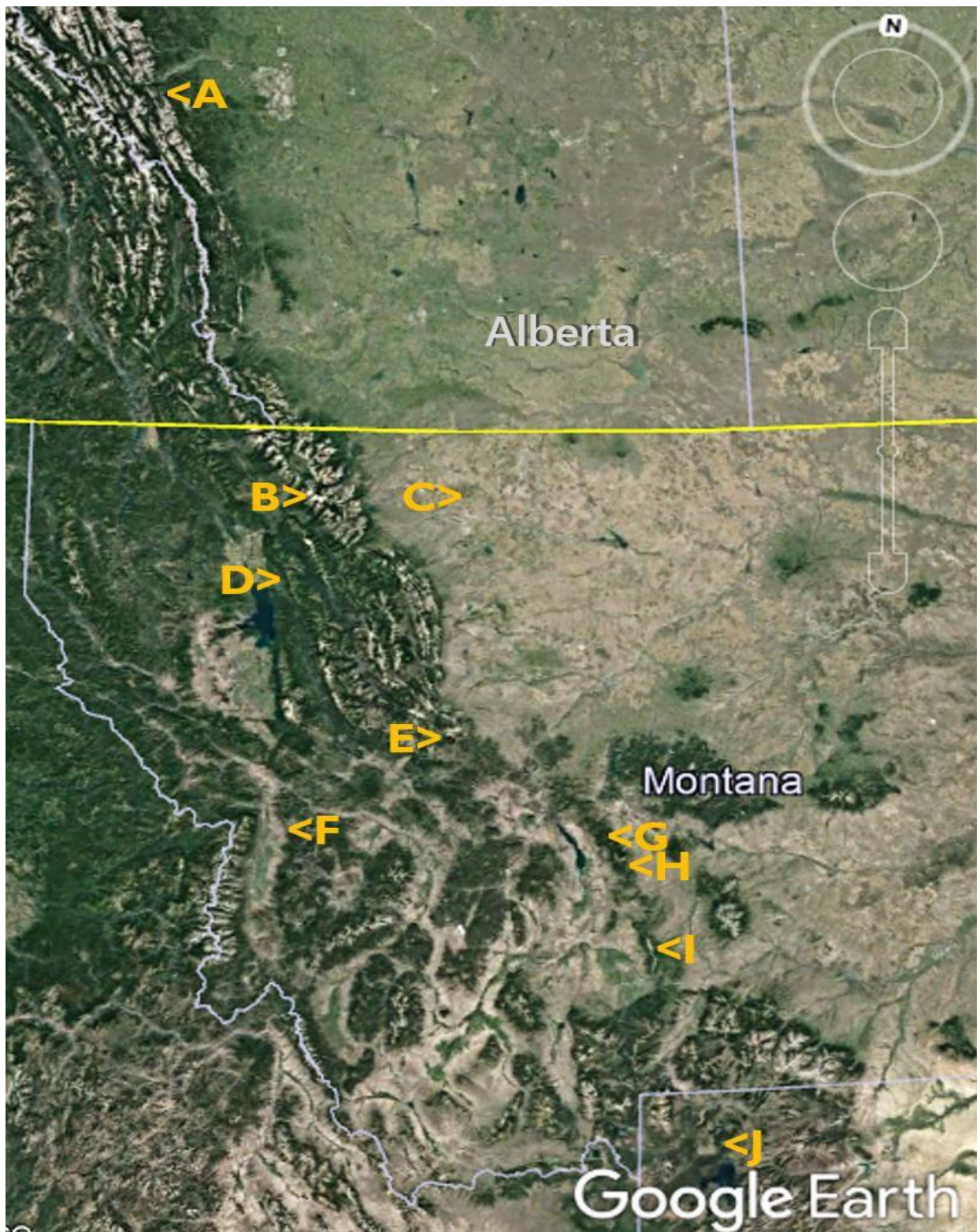


Figure 1. Approximate locations of hawk-count sites in Montana and Alberta, Canada, during 2018 fall migration surveys. A) Mt. Lorette (Alberta); B) Mt. Brown (Glacier National Park); C) Cut Bank; D) Jewel Basin; E) Roger's Pass; F) MPG Ranch; G) Big Belts; H) Grassy Mountain; I) Bridgers; J) Hayden Valley (Yellowstone National Park).

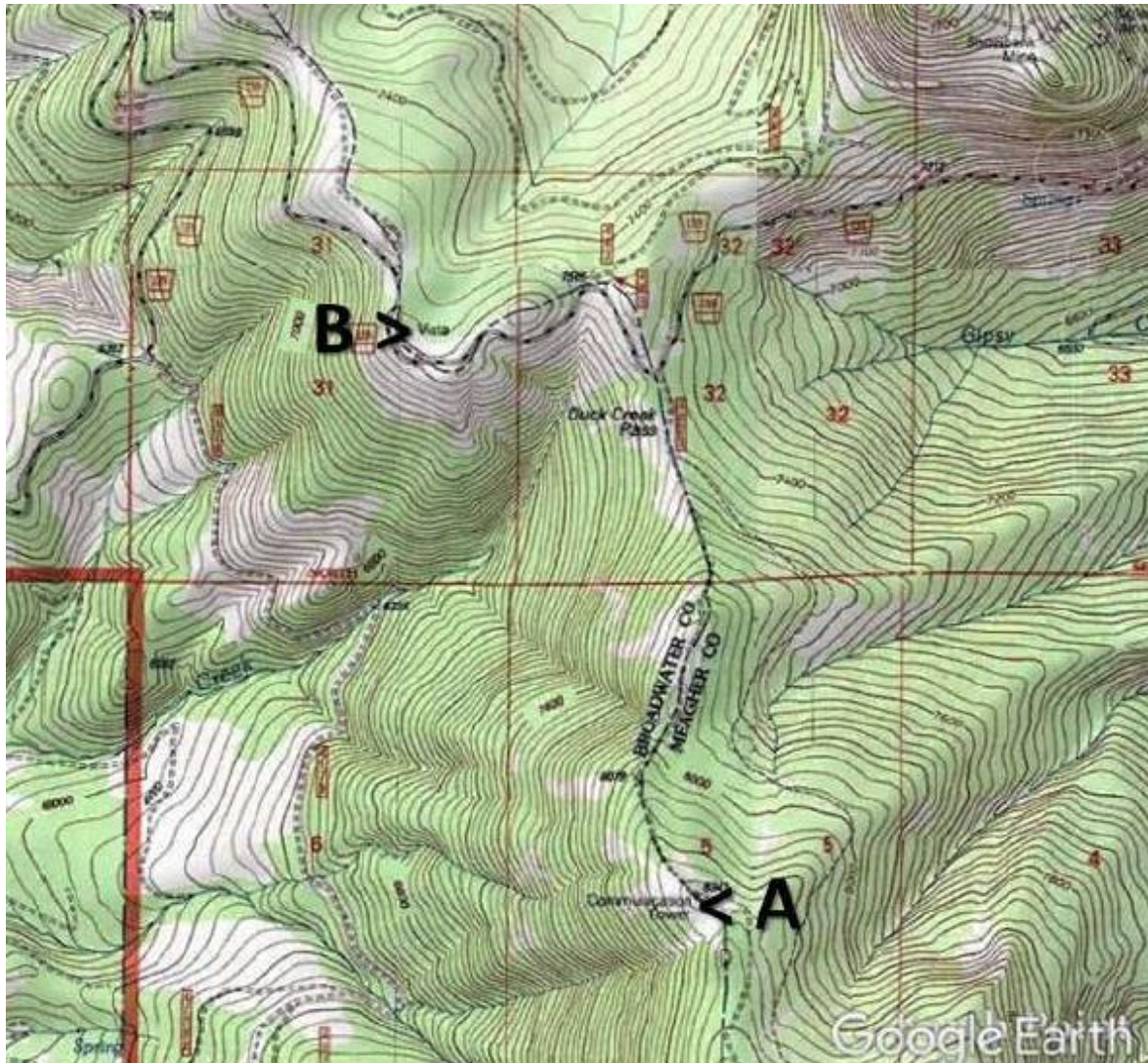


Figure 2. Location of Big Belts raptor migration observation sites utilized during the 2018 fall survey period. A) Radio Tower West Slope (RTWS - Primary Site); B) Vista Points (VP - Secondary Site).

Methods

In 2018, Amy Seaman, Montana Audubon employee, and two well-qualified U.S. Forest Service employees, Erin Reather and Shaun Hyland acted as the primary observers for the GEMS Project. No observers were camped at the typical Duck Creek Pass location, and due to shorter project staffing, partners had a four day per week survey objective. The season started on 5 September and ended on 24 October after many days of low-lying clouds and inclement weather. There was a focus on Golden Eagles, whose migration is later in September. No additional observers were trained in 2018, however nine volunteers committed time to observing.

Observation hours began regularly at 0900, and on most days concluded at 1700 (MST). During Peak rates of Golden Eagle migration the observers attempted to count more than four days per week, weather permitting. Both Vista Point (VP) and Radio Tower West Slope (RTWS) were utilized during 2018 counts. Data, including raptor numbers and weather observations, were recorded following HawkWatch International protocol. Weather was measured with a handheld Kestrel 2500 Weather Station. Two decoy owls were used at the RTWS lookout to lure migrating raptors closer to the observers, to enhance opportunities for proper identification. The owl 80m downslope from the site was lost to the elements after just three weeks.

Each day observers recorded:

1. Species, age, sex and color morph of each migrant raptor, whenever possible and applicable (Appendix A lists common/scientific names for all species, species-specific applicability of various age, sex, and color morph distinctions, and two letter codes used for each species).
2. Hour of passage for each migrant (e.g., the 0900–0959 H, etc - Mountain Standard Time).
3. Hourly wind speed and direction, air temperature, percent cloud cover, predominant cloud type(s), presence of precipitation (and type), visibility, and a subjective assessment of thermal lift conditions (i.e., excellent, good, fair and poor) – assessed on the half-hour.
4. Predominant direction, altitude, and horizontal distance from the observation point of the migratory flight for each hour.
5. Total minutes observed, and the mean number of observers present during each hour (including official observers plus volunteers/visitors who contributed substantially to the count [actively scanning, pointing out birds, recording data, etc.] for at least 10 minutes in a given hour).
6. A subjective visitor-disturbance rating (high, moderate, low, none) for each hour.

In 2018, behavior of resident raptors was not closely detailed, as no two observers spent more than two days in the field in a row. Data was entered on both paper data sheets, and on Dunkadoo (dunkadoo.org), an in-field electronic data entry program accessible via smart devices. HMANA's (Hawk Migration Association of North America) website, hawkcount.org, was automatically updated via Dunkadoo at the end of each day. The GEMS migration site on the hawkcount.org website is listed as “Golden Eagle Migration Survey” (GEMS) and hourly raptor count totals and daily weather summaries were also posted. Regular postings with updates were regularly shared with Audubon Chapters and on Montana Audubon's Facebook page.

Observation Effort & Weather Summary

With our U.S Forest Service partners, we completed a total of 26 survey days between 5 September and 30 October, recording 2,286 individual migrant raptors representing 16 raptor species. Counts were made on 24 days from the RTWS site, and on 2 days from SK. Visibility throughout the season was high when the site was not cloud-covered, despite some low-lying haze to the west. Smoke from fires was considerably less of a visibility in 2018 than in 2017. Pulses of storms that brought snow below 7000' caused intermittent gaps in survey opportunity. Because no full-time observers were at the site, partial counts were not conducted on these stormy days. A large snow drift before the pass built up around October 11th, and storms ceased observations on 3 days.

Results

Between 5 September and 24 October 2018, 2,286 individual migrant raptors representing 16 raptor species were recorded. The total includes 1,503 Golden Eagles, 216 Sharp-shinned Hawks, 95 Red-tailed Hawks, 93 Bald Eagles, 86 Cooper's Hawks, 84 Rough-legged Hawks, 44 Northern Goshawks, 41 American Kestrels, 28 Northern Harriers, 18 Peregrine Falcons, 12 Broad-winged Hawks, 8 Prairie Falcons, 9 Merlin, 6 Turkey Vultures, 6 Osprey, 4 Swainson's Hawks, and 1 Ferruginous Hawk. The remainder were unknown species simply recorded to family.

This spectacular eagle-viewing site continues to see peak numbers during the 2nd and 3rd weeks of October, and this year's high count of 343 Golden Eagles occurred on October 18th after the passing of a cold front a few days before. In the eight survey days surrounding that peak, 962 Golden Eagles (64% percent of those counted in 2018) were counted migrating past the site.

The 2018 count proved to be roughly more similar in numbers to the 2017 count than the first two seasons. In 2017, 2,929 individual migrant raptors were counted during 41 survey days, and 2,159 of these were Golden Eagles. (74% percent of migrants counted in 2017). Though Golden Eagle passage rates were similar in all years, much higher numbers of all raptors were counted in 2015 and 2016 with a total of 4,318 and 4,389 respectively. The overall number of birds of each taxa passing has remained similar at the site during all four count years (Fig. 3).

Golden Eagles

In 2018 Golden Eagles passed at a rate of 473 per 100 hours of observation time compared to a higher rate of 732 per 100 hours of observation in 2017. A total of 1503 were counted. This could be due to more sporadic observations in 2018. Observers recorded a total of 139 immature or first year Golden Eagles, 389 Non-adults, 737 adults, and 238 of unknown age (Fig. 4). On 11 of 26 count days, raptor migration counts were also being conducted ~ 15 miles south at a site called Grassy Mountain. Counters there recorded similar numbers of birds on those days, however there were a few anomalies. On days with stronger east winds, counts tended to be higher at Duck Creek, however on most days, the counts were similar.

Age-specific data were collected for 97% of all Golden Eagles observed. Due to the difficulty of accurately distinguishing immature (hatch-year) Golden Eagles from older subadults in the field, and for the purposes of this report, the non-adult category includes all birds identified in the field as immature, sub-adults (generally birds that are 1.5-3.5 years of age), or non-adults (see Appendix A). In total, adult birds generally outnumbered non-adult birds (737 adults counted versus 529 non-adults, see Table 1, Figures). Although long-term demographic data do not yet exist for the Big Belt flyway, the Bridger Raptor Migration Project has been collecting detailed age data on migrating Golden Eagles since 1991, providing a useful comparison for our age-specific observations in the Big Belts (which may provide valuable information on breeding success). In fall 2017 the ratio of non-adult-to-adult Golden Eagles using the Big Belt flyway was 0.65:1, and in 2018 was 0.71:1 This is well below the 1992-2015 average non-adult-to-adult ratio in the Bridgers (1.1:1). This pattern of age disparity between the two sites is evident throughout the three-year history of the GEMS Project and may suggest age-specific differences in migration routes. At this time we are unable to confidently explain this consistent age-specific disparity between the Bridgers and the Big Belts.

Table 1. Flight summary for all migrating raptors observed in the Big Belt Mountains, fall 2018. Given are species, total counted for each species and dates of first and last detection. Data for adult (A) and non-adult (NA) Golden Eagles are given as well as total.

Species	Total	First Observed	Last Observed
Golden Eagle (A)	741	5 - Sept	24 - Oct
Golden Eagle (NA)	527	5 - Sept	24 - Oct
Golden Eagle (Total)	1503	5 - Sept	24 - Oct
Sharp-shinned Hawk	216	5 - Sept	24 - Oct
Red-tailed Hawk	95	5 - Sept	24 - Oct
Bald Eagle	93	5 - Sept	24 - Oct
Cooper's Hawk	86	5 - Sept	18 - Oct
Rough-legged Hawk	84	3 - Oct	24 - Oct
Northern Goshawk	44	5 - Sept	24 - Oct
American Kestrel	41	5 - Sept	19 - Oct
Northern Harrier	28	5 - Sept	22 - Oct
Peregrine	18	6 - Sept	1 - Oct
Broad-winged Hawk	12	12 - Sept	22 - Sept
Merlin	3	15 - Sept	20 - Oct
Prairie Falcon	8	6 - Sept	12 - Oct
Turkey Vulture	6	6 - Sept	25 - Sept
Osprey	6	8 - Sept	22 - Sept
Swainson's Hawk	4	5 - Sept	15 - Sept
Ferruginous Hawk	1	22 - Sept	22 - Sept

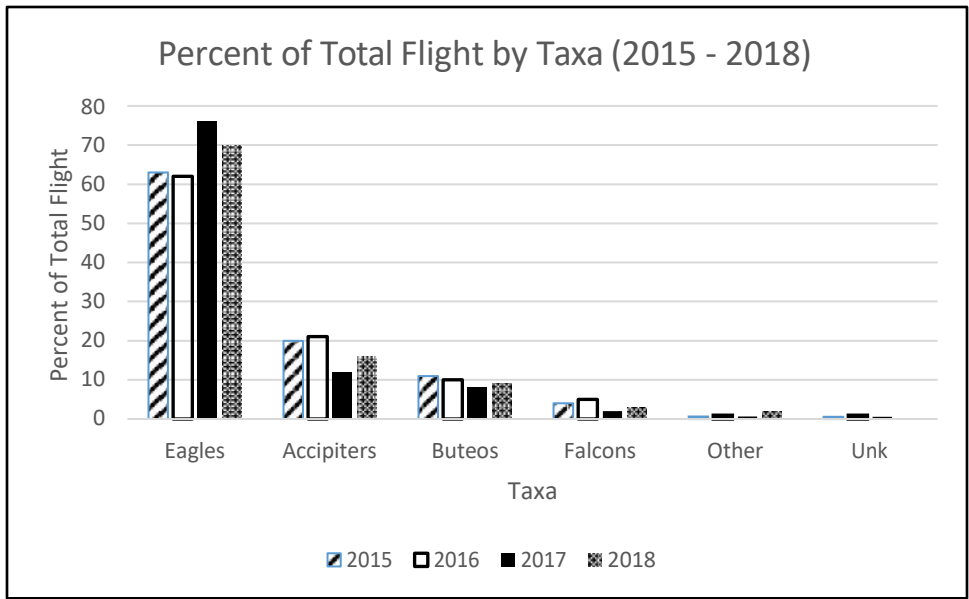


Figure 3. Percent of total flight by taxa – fall 2015, 2016, 2017, & 2018. ‘Other’ category includes Turkey Vultures, Ospreys, and Northern Harriers. ‘Unknown’ category is comprised of totally unidentified raptors. Both ‘Unknown’ and ‘Other’ categories each made up <1% of the count 2015-2017. In 2018 ‘Other’ made up ~2% and ‘Unknown’ were much less than 1%.

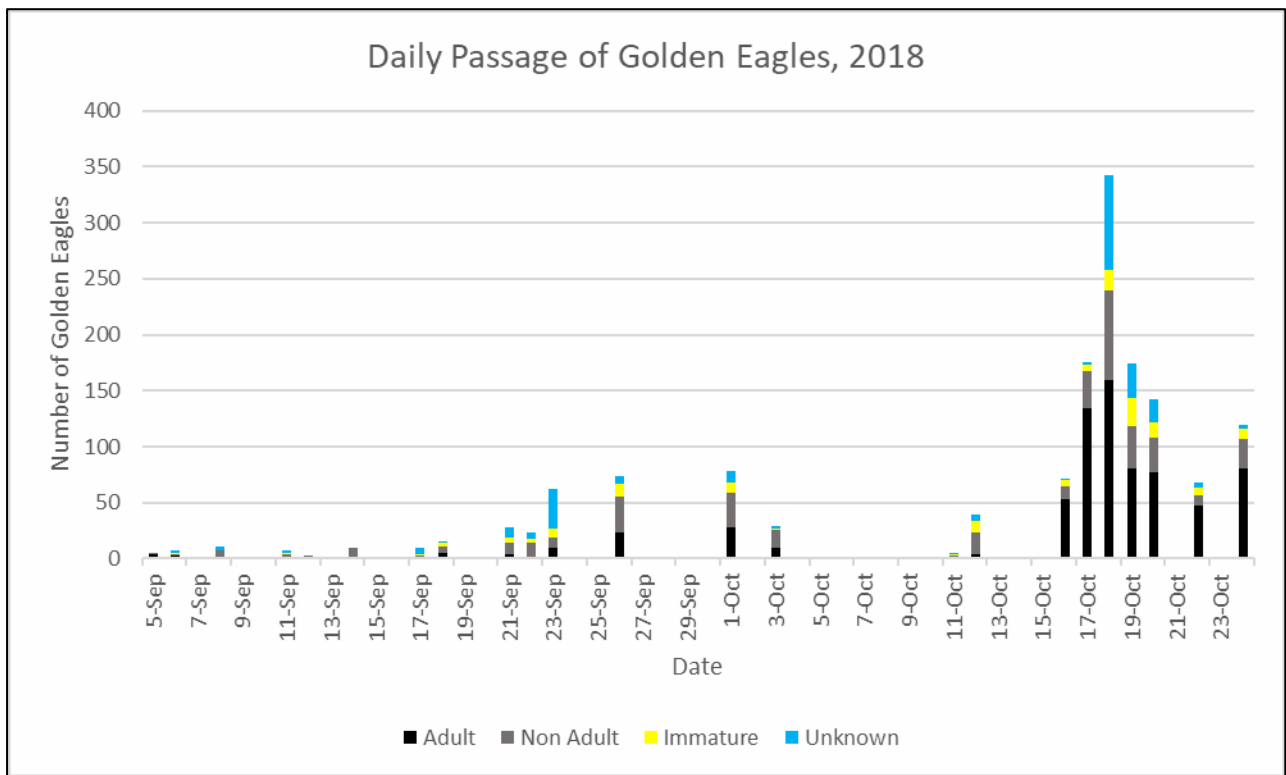


Figure 4. Total Golden Eagle flight by age class in the Big Belt Mountains in fall 2018. All non-adult Golden Eagles (immature, subadults, and non-adults; see Appendix A) were combined to a single non-adult category when calculating non-adult: adult ratios.

Other Avian Wildlife

Daily e-Bird lists were kept opportunistically during Montana Audubon staff observations at RTWS. Birds recorded include Gray Jay, Dark-eyed Junco, Common Raven, Mountain Chickadee, Yellow-rumped Warbler, Mountain Bluebird, American Crow, American Pipit, Cassin's Finch, Clark's Nutcracker, American Robin, Pine Siskin, Dusky Grouse, White-throated Swift and Northern Flicker. Gray Jays were observed most frequently. American Pelicans and many gulls were also seen migrating south during the count. Resident raptors were less evident without observers permanently stationed near the count site, but some observations were contributed to bird species were documented on the 'Golden Eagle Migration Survey (GEMS) hawk watch' hotspot on eBird.org (<https://ebird.org/hotspot/L4988893>).

Publicity and Public Visitation

Acknowledging that attention was heavily drawn to the RTWS observation site during the first three years of surveying, potentially to the detriment of the project, the GEMS committee took a lower profile approach to publicity in 2018. This was primarily driven by safety concerns. One season summarizing article ran in the Helena Independent Record on December 19th, 2018. <https://bit.ly/2rzLOSs>. We ran an article about the project in our fall Montana Audubon 2018 print newsletter. Public visitation was also limited for these reasons, although 9 volunteers assisted with observations at the site and half a dozen visitors stopped by. One field trip was organized by Montana Audubon during the 2018 season (13 October), however weather precluded accessing the site and the field trip that hosted eight participants, was carried out in the foothills. Montana Audubon Executive Director Larry Berrin instructed field trip participants on raptor identification prior to the field trip.

Problems, Recommendations, Lessons learned, & Ongoing Work.

In 2018, as in 2017, early and persistent snow drifts, and low-lying clouds made the observation site both hard to access and had low visibility once accessed. Unfortunately, the typically easier to access east side of the pass road had experienced severe wash-outs over the summer so that the site was only accessed by passenger vehicles with difficulty. The site however, continues to afford observers exceptionally close views of both Golden and Bald Eagles, allowing accurate demographic data to be collected as birds pass south. We recommend continuing the target survey end date of October 31st. Our start date of September 5th was close to the recommended date of September 1st, but because training was not required, observers were able to get straight to work. We would also recommend ongoing use of the wall tent, wood stove, and camper to provide some degree of comfort for the observers, if full-time observers are hired in 2019. Additionally, an added complication of full-time occupancy of the Duck Creek site was a newly implemented food-storage order to take bear occupancy into consideration. This was not the case in previous years, and changes will be needed at the camp to address these changes. Because observers traveled daily to the site, starting right at 0900 was often difficult, though observations often began before 1000. If the project is continued with staffing levels similar to 2018, observers could focus effort on the peak of Golden Eagle migration later in the season.

As in past years, the majority of Golden Eagles were counted during the 2nd and 3rd weeks of October. In the eight survey days surrounding the peak of Golden Eagle Migration (18 October with 349 counted), 962 Golden Eagles (64% percent of those counted in 2018) were counted migrating past the site. Golden Eagles were counted during 25 days of counting. A benefit of continuing to survey throughout the migratory period is that observers can better capture potential changes in seasonal timing of raptor migration driven by climate change. More evidence suggests this process may be in effect (Filippi-Codaccioni et al. 2010 & Therrien et al. 2017).

Our partnership with the U.S. Forest Service was paramount to conducting surveys in 2018. Additionally, support by the U.S. Forest Service for vehicle safety training, and vehicle support to the survey site underpinned the ability of Montana Audubon to access the survey site. Montana Fish, Wildlife & Parks continued to be a strong partner on the GEMS committee, and outreach (including raptor identification programming, a field trip, and many newsletters) continued to be an integral component of the GEMS project for Montana Audubon. Financial and staffing support from the U.S. Forest Service was further critical to the project's success. We encourage expanding existing collaborations and seeking new partnerships other potential partners in the future and we hope to continual leading education opportunities at the site.

Based on the first four seasons of study in the Big Belts, we recommend the Golden Eagle Migration Survey be continued annually. There is tremendous value in continuing this standardized, long-term, science-based raptor migration count, with the primary focus on assessing the long-term health and trends of the Rocky Mountain migratory Golden Eagle population. Because the site continues to be difficult to access during periods of inclement weather, and given the poor road conditions of the typically easier to access east side of Duck Creek Pass, we recommend continuing conversations within the GEMS committee, and with RVRI, to investigate the potential to move this high elevation count site closer to the newly commenced Grassy Mountain count (conducted in partnership between RVRI and Teton Raptor Center). Numbers of migrating raptors counted during raptor banding efforts there were similar on days with consecutive counts, while access is much easier. We believe continued raptor migration monitoring along the Big Belts corridor does complement other counts in the region. We will seek to continually fund this long-term effort.

It is important to remember that the purpose of the GEMS count is to obtain a standardized, credible, science-based data set to assess long-term population health and change; it is not to count as many raptors as possible. Some changes were put into place in 2018 for observer safety during times of especially inclement weather. Previously, observers have been required to maintain their post as long as conditions were suitable for migrant raptors to be seen. In 2018, observation hours were cut-off automatically at 1700 to reduce excess observer exposure. However, conducting the count in the Big Belts has proven to be daunting in times of severe weather. Exceptionally high winds (>70 mph recorded) and sub-zero wind chills can threaten observer health and safety. Fortunately in 2018 severe weather was not encountered, however as mentioned previously, observers rarely stayed over-night near the observation site.

Acknowledgements

We want to thank partners for another year's worth of collaboration on the GEMS Project. The unique contributions of Montana Audubon (MA), the U.S. Forest Service (U.S.F.S.; Helena-Lewis & Clark National Forest) and Montana Fish, Wildlife, & Parks (FWP) made the 2018 survey season possible. We also have many individual financial contributors to be thankful for. As in past years, the GEMS observers greatly appreciated the timely, informative Golden Eagle migration updates from Mt. Lorette (in Alberta, Canada), reported via email almost daily by Peter Sherrington, Founder and President of the Rocky Mountain Eagle Foundation and from Raptor View Research Center (Rob Domenech) and Teton Raptor Center (Brian Bedrosian) who conducted research at the Grassy Mountain Site to the South.

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APPENDICES

Appendix A. Common and scientific names, species codes, and age, sex and color-morph classifications for all diurnal raptor species observed during fall migration in the Big Belt Mountains, MT.

COMMON NAME	SCIENTIFIC NAME	SPECIES CODE	AGE ¹	SEX ²	COLOR ₃ MORPH
Turkey Vulture	<i>Cathartes aura</i>	TV	U	U	NA
Osprey	<i>Pandion haliaetus</i>	OS	U	U	NA
Northern Harrier	<i>Circus cyaneus</i>	NH	A I Br U	M F U	NA
Sharp-shinned Hawk	<i>Accipiter striatus</i>	SS	A I U	U	NA
Cooper's Hawk	<i>Accipiter cooperii</i>	CH	A I U	U	NA
Northern Goshawk	<i>Accipiter gentilis</i>	NG	A I U	U	NA
Unknown small accipiter	<i>A. striatus</i> or <i>cooperii</i>	SA	U	U	NA
Unknown large accipiter	<i>A. cooperii</i> or <i>gentilis</i>	LA	U	U	NA
Unknown accipiter	<i>Accipiter</i> spp.	UA	U	U	NA
Broad-winged Hawk	<i>Buteo platypterus</i>	BW	A I U	U	DLU
Swainson's Hawk	<i>Buteo swainsoni</i>	SW	U	U	DLU
Red-tailed Hawk	<i>Buteo jamaicensis</i>	RT	A I U	U	DLU
Ferruginous Hawk	<i>Buteo regalis</i>	FH	A I U	U	DLU
Rough-legged Hawk	<i>Buteo lagopus</i>	RL	U	U	DLU
Unknown buteo	<i>Buteo</i> spp.	UB	U	U	DLU
Golden Eagle	<i>Aquila chrysaetos</i>	GE	I, S, NA, A, U ⁴	U	NA
Bald Eagle	<i>Haliaeetus leucocephalus</i>	BE	I, S1, S2, NA, A, U ⁵	U	NA
Unknown eagle	<i>Aquila</i> or <i>Haliaeetus</i> spp.	UE	U	U	NA
American Kestrel	<i>Falco sparverius</i>	AK	U	M F U	NA
Merlin	<i>Falco columbarius</i>	ML	AM Br	AM U	NA
Prairie Falcon	<i>Falco mexicanus</i>	PR	U	U	NA
Peregrine Falcon	<i>Falco peregrinus</i>	PG	A I U	U	NA
Unknown small falcon	<i>F. sparverius</i> or <i>columbarius</i>	SF	U	U	NA
Unknown large falcon	<i>F. mexicanus</i> or <i>peregrinus</i>	LF	U	U	NA
Unknown falcon	<i>Falco</i> spp.	UF	U	U	NA
Unknown raptor	<i>Falconiformes</i>	UU	U	U	NA

¹ Age codes: A = adult, I = immature, Br = brown (adult female or immature), U = unknown age.

² Sex codes: M = male, F = female, U = unknown.

³ Color morph codes: D = dark or rufous, G = gray; L = light, W = white; U = unknown, NA = not applicable.

⁴ Golden Eagle age codes: I = Immature: juvenile or first-year bird, bold white wing patch visible below, bold white in tail, no molt; S = Subadult: white wing patch weak or absent, obvious white in tail and molt or tawny bar visible on upper wing; NA = Not adult: unknown age immature/subadult; A = Adult: no white in wings or tail; U = Unknown.

⁵ Bald Eagle age codes: I = Immature: juvenile or first-year bird, dark breast and tawny belly; S1 = young Subadult: Basic I and II plumages, light belly, upside-down triangle on back; S2 = older Subadult: Basic III plumage, head mostly white with osprey-like dark eye line and usually a dark terminal band on tail; NA = Not adult: unknown age immature/subadult; A = Adult: includes near adult with dark flecks in head and weak dark tail tip, and adult with completely white head and tail; U = Unknown.

Appendix B. A complete history of official observers for the Golden Eagle Migration Survey in the Big Belt Mountains (2015-2017). Numbers given in parentheses indicate the number of full seasons of previous raptor migration counting experience.

2015: Two observers throughout: Bret Davis (4), Ronan Dugan (0)

2016: Two observers throughout: Jeff Grayum (0), Ronan Dugan (1)

2017: Two observers throughout: Jeff Grayum (1), Hilary Turner (0)

2018: One observer ~ 2x week: Amy Seaman (2)

Appendix C. Daily observation effort and raptor migration counts by species in the Big Belt Mountains, MT, fall 2017 (see Appendix A for species codes)

Date	Obs. Hours	SS	CH	NG	UA	RT	RL	SW	FH	BW	UB	AK	PG	PR	ML	UF	GE	BE	UE	TV	NH	OS	UU	Grand Total	Birds per Hour
5-Sep	7.5	6	1	2	0	1	0	1	0	0	0	2	0	0	0	0	5	5	0	0	1	0	0	24	3.2
6-Sep	6	6	3	0	0	0	0	1	0	0	0	4	1	1	0	0	7	1	0	1	0	0	0	25	4.2
8-Sep	7	6	2	2	1	3	0	0	0	0	0	4	0	1	0	1	11	0	0	0	3	2	0	36	5.1
11-Sep	8	4	5	2	0	0	0	1	0	0	1	2	0	0	0	0	7	2	0	0	2	1	0	27	3.4
12-Sep	7	3	1	0	0	0	0	0	0	1	0	0	0	0	0	0	3	1	0	0	0	0	0	9	1.3
13-Sep	5	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4	0.8
14-Sep	6.5	9	15	0	2	7	0	0	0	2	0	3	2	1	0	0	10	2	0	0	0	1	1	55	8.5
15-Sep	7.25	1	2	1	0	5	0	1	0	1	0	0	1	0	1	0	2	0	0	1	0	0	0	16	2.2
17-Sep	8	9	7	1	0	4	0	0	0	1	1	0	1	0	1	0	10	0	0	0	1	1	0	37	4.6
18-Sep	8	10	10	1	0	4	0	0	0	1	0	2	1	1	1	0	16	2	0	0	3	0	0	52	6.5
21-Sep	7.5	10	4	2	2	8	0	0	0	3	0	1	2	0	0	0	28	2	0	2	0	0	1	65	8.7
22-Sep	7.75	29	18	8	4	21	0	0	1	3	0	14	5	1	2	2	24	3	0	0	7	1	3	146	18.8
25-Sep	8	8	3	2	0	2	0	0	0	0	0	0	0	1	1	0	62	0	0	2	0	0	0	81	10.1
26-Sep	8	11	1	2	1	7	0	0	0	0	0	3	2	2	1	0	74	5	0	0	0	0	0	109	13.6
1-Oct	8	16	1	2	0	7	0	0	0	0	0	3	3	0	0	1	78	0	0	0	0	0	0	111	13.9
3-Oct	7.5	8	6	1	0	9	4	0	0	0	0	2	0	0	0	0	29	4	0	0	4	0	1	68	9.1
10-Oct	5.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
11-Oct	6.5	0	0	1	0	0	1	0	0	0	2	0	0	0	0	0	5	0	0	0	0	0	0	9	1.4
12-Oct	7	7	0	0	0	1	3	0	0	0	0	0	0	1	0	0	39	4	0	0	1	0	0	56	8.0
16-Oct	6.5	8	2	1	0	3	7	0	0	0	0	0	0	0	0	0	71	2	0	0	0	0	0	94	14.5
17-Oct	7.5	10	2	1	0	2	5	0	0	0	0	0	0	0	0	0	176	12	0	0	4	0	0	212	28.3
18-Oct	8.5	18	2	3	0	3	23	0	0	0	0	0	0	0	1	0	342	9	0	0	1	0	0	402	47.3
19-Oct	6.6	10	0	3	3	1	18	0	0	0	0	1	0	0	0	0	174	10	0	0	0	0	0	220	33.3
20-Oct	6.6	9	0	2	1	1	3	0	0	0	0	0	0	0	1	0	142	10	0	0	0	0	0	169	25.6
22-Oct	7.1	13	0	3	1	3	16	0	0	0	0	0	0	0	0	0	68	4	0	0	1	0	1	110	15.5
24-Oct	7.25	4	0	4	0	3	4	0	0	0	0	0	0	0	0	0	119	15	0	0	0	0	0	149	20.6
TOTAL	185.8	216	86	44	16	95	84	4	1	12	4	41	18	9	9	4	1503	93	0	6	28	6	7	2286	308.35

Species names are: SS (Sharp-shinned Hawk), CH (Coopers Hawk), NG (Northern Goshawk), UA (Unk. Accipiter), RT (Red-tailed Hawk), RL (Rough-legged Hawk), SW (Swainson's Hawk); FH (Ferruginous Hawk); BW (Broad-winged Hawk); UB (Unk. Buteo); AK (American Kestrel); PG (Peregrine Falcon); PR (Prairie Falcon); ML (Merlin); UF (Unk. Falcon); GE (Golden Eagle); BE (Bald Eagle); UE (Unknown Eagle); TV (Turkey Vulture); NH (Northern Harrier); OS (Osprey); UU (Unk. raptor)

* Counts conducted on 13-Sep and 11 - Oct were from the Saddle Knoll Site.

Appendix D. Annual observation effort and fall raptor migration counts by species in the Big Belt Mountains, MT: 2015–2018. Mean for each species is only calculated for 2015–2017 because of the difference in number of survey days.

	2015	2016	2017	2018	Mean
Start date	15-Sep	1-Sep	15-Sep	5-Sep	10-Sep
End date	2-Nov	5-Nov	31-Oct	24-Oct	30-Oct
Observation days	46	60	41	26	43
Observation hours	352.8	443.4	295.0	185.8	319.3
Raptors / 100 hours	1244	974	993	808	1,004
SPECIES	RAPTOR COUNTS				
Turkey Vulture	3	1	1	6	2
Osprey	9	17	1	6	9
Northern Harrier	32	45	15	28	31
Sharp-shinned Hawk	656	673	232	216	520
Cooper's Hawk	102	116	67	86	95
Northern Goshawk	85	107	60	44	84
Unidentified Accipiter	42	38	23	16	34
Total Accipiters	885	934	382	362	734
Broad-winged Hawk	29	17	1	12	16
Swainson's Hawk	2	2	1	4	2
Red-tailed Hawk	176	203	81	95	153
Ferruginous Hawk	7	2	0	1	3
Rough-legged Hawk	215	214	127	84	185
Unidentified Buteo	29	19	13	4	20
Total Buteos	458	457	223	200	379
Golden Eagle	2630	2620	2159	1503	2470
Bald Eagle	104	116	65	93	95
Unidentified Eagle	3	4	7	0	5
Total Eagles	2727	2740	2231	1596	2659
American Kestrel	59	83	12	41	51
Merlin	58	30	11	9	33
Prairie Falcon	19	15	10	9	15
Peregrine Falcon	36	28	5	18	23
Gyr Falcon	0	0	0	0	0
Unidentified Falcon	8	13	10	4	10
Total Falcons	180	169	48	81	132
Unidentified Raptor	14	26	28	7	23
Grand Total	4318	4389	2929	2286	3879