An Investigation into Historical and Contemporary Breeding Occurrence of the Ferruginous Hawk in Kansas

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AN INVESTIGATION INTO HISTORICAL AND CONTEMPORARY

 BREEDING OCCURRENCE OF THE

 FERRUGINOUS HAWK IN

 KANSAS

A Thesis Presented to the Graduate Faculty
of Fort Hays State University in
Partial Fulfillment of the Requirements for
the Degree of Master of Science

by

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ABSTRACT

The Ferruginous Hawk (*Buteo regalis*) is the largest *Buteo* species occurring in grasslands, nesting along bluffs, buttes and isolated trees. In Kansas, the Ferruginous Hawk is listed as a Species of Greatest Conservation Need, Tier II. A previous study on Ferruginous Hawks nesting in Kansas during the years of 1979 to 1987, with sporadic visits from the 1990s to 2000, revealed that the most productive nesting territories were inaccessible to predators, placed on rocky ledges and the surrounding landscape was over 50% rangeland. I revisited 82 of the 111 historic nest territories in the summers of 2019 and 2020. When a nest was found I flew a drone above the nest to determine if it was occupied and to photograph the nest contents. Of the 82 territories searched, 10 territories were occupied with a total of 18 chicks in 2019 and in 2020, 13 territories were occupied with a total of 17 chicks. All nests were placed on rocky ledges or columns. The findings of this study will be used by KDWPT to determine conservation practices that ensure the persistence of the Ferruginous Hawk in contemporary rangelands.
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INTRODUCTION

Birds of prey play a key role in ecological systems worldwide. This is due to many factors, including their carnivorous diet, scavenging habits and their role at the top trophic level. As members of the top trophic level, they are the main contributors to regulating pest species levels such as rodents. Many species of raptors, such as Great Horned Owls (Bubo virginianus) and Golden Eagles (Aquila chrysaetos), exist as the apex predator in their respective ecosystems. The presence or absence of these apex predators can be used for conservation, as flagship species, of particular ecosystems or other avian, mammalian and vegetation species (Donázar et al. 2016, Lindenmayer & Likens 2011, Burgas et al. 2014, Caro 2010, Sergio et al. 2008). While some birds of prey are solely predatory there are many species that will readily scavenge or rely entirely on scavenging. By reducing carrion these birds also greatly minimize the spread of diseases in ecosystems, and due to these efforts, associated diseases of pest species are also reduced (Donázar et al. 2016). To continue the ecosystem services provided by birds of prey, special attention must be paid towards conserving the birds, their prey and habitats.

The Ferruginous Hawk, Buteo regalis, is the largest of the Buteo hawk species in North America. Their breeding range extends over most of the Western North America, from Southern Canada to Northern Arizona and New Mexico, and from the California border east to Western Nebraska and Kansas. During the winter they occur from Texas and Kansas west to California and south to Central Mexico. The Ferruginous Hawk inhabits grasslands or shrub-steppe with sparse trees, canyons, sandsage and rock outcrops (Ng et al. 2020). In Kansas, Ferruginous Hawk nests occur in the grasslands of the Central Great Plains and High Plains regions in the western half of the state.
Ferruginous Hawks build nests in trees, shrubs, cliffs, human-made structures (e.g., utility poles or nest platforms) and ground outcrops. Nest building begins in early March, either building a new nest or modifying abandoned corvid or raptor nests. Materials such as sticks and twigs are added and the nest is usually lined with bark or cow dung (Roth and Marzluff 1989). Typically, multiple nest sites will be started before the pair chooses one as a breeding site. These false starts can make searching for active nests difficult. Ferruginous Hawks have only one brood per season consisting of one to four chicks, although up to eight chicks in a brood have been observed. Some research has documented higher nest success for nests on anthropogenic structures and higher success raising fledglings (Wiggins et al. 2014). Ferruginous Hawks begin breeding as young as two years old and potentially live up to 20 years in the wild (Ng et al. 2020).

Nesting success depends on multiple factors, but the two most critical are prey abundance and disturbances to nesting territory (Keeley et al. 2016, Coates et al. 2014). Disturbances to nesting territory can vary by ecosystem but are mainly human-driven landscape changes such as energy development or habitat fragmentation. Nest placement is influenced by the inaccessibility of the nest area to quadrupedal predators and distance to some anthropogenic disturbances such as oil wells (Roth & Marzluff 1989, White & Thurow 1985, Wiggins et al. 2017). The nesting territory, defined as an area historically containing a nest site of only one mated pair, of Ferruginous Hawks is approximately 90 km (Leary et al. 1998). Compared to other Buteo species (Red-tailed Hawk [Buteo jamaicensis] and Swainson’s Hawk [Buteo swainsoni]), Ferruginous hawks prefer to nest farthest away from human habitation and within a higher percentage of grassland in the area surrounding the nest (Bechard et al. 1990). Wintering Ferruginous Hawks occur in grasslands and desert as far north as Colorado and California and extending south,
where prey is sufficient but habitat is less important than prey availability (Plumpton and Andersen 1998). During winter, Ferruginous Hawks will roost closer to croplands than they nest during the breeding season because croplands provide a source of winter prey (Schmutz 1987).

The diet of the Ferruginous Hawk consists of ground squirrels (*Spermophilus spp.*), prairie dogs (*Cynomys spp.*) and pocket gophers (*Geomys spp.* and *Thomomys spp.*) east of the continental divide and rabbits (*Sylvilagus spp.*, and *Lepus spp.*) west of the continental divide. Their hunting methods vary from short dives off nearby perches to waiting on the ground near a burrow and pouncing on prey (Ng et al. 2017). In Kansas, most nests were built within eight km of black-tailed prairie dog (*Cynomys ludovicianus*) towns, suggesting that prairie dogs may be a major prey source (Roth and Marzluff 1989). The presence of nearby perches at prairie dog towns can allow for multiple hawks to hunt and roost.

Ferruginous Hawks face several human-driven threats to their survival. Wind energy structures can be harmful due to loss of nesting and hunting habitat due to fragmentation and from collisions with wind turbine structures by adults and juveniles (Kolar 2016). Ferruginous Hawks also may be struck by cars while feeding on roadkill. The eradication of prairie dogs has negatively affected Ferruginous Hawk populations by reducing food availability and increasing the risk of secondary poisoning (Vyas et al. 2017). Ferruginous Hawks are sensitive to human disturbance while nesting and will flush from humans approaching on foot at distances of 250-500 m (White & Thurow 1985, Nordell 2016). They are also sensitive to the use of agricultural machines and agricultural developments (Schmutz 1987). Re-use of previous nests decreased with an increase in nearby facilities for oil and gas extraction and with frequent presence of humans (Wiggins et al. 2014).
Unoccupied Aerial Systems or drones are a relatively new technology that is being applied to many aspects of biological research, spanning from monitoring of invasive species, vegetation surveys, forestry research to monitoring for illegal poaching (Rivas-Torres et al. 2018, Lina & Guofan 2015, Mulero-Pázmány et al. 2014). One of the most advantageous characteristics of drone use is the light footprint or impact on the research subjects and the surrounding environment, particularly in the case of sensitive species. Use of drones also lowers operating costs and is less hazardous for researchers compared to crewed aircraft surveys. Of note, one of the leading causes of deaths of biologist researchers over the last century has been aviation accidents while performing aviation surveys (Sasse 2003). Drones also have advanced GPS systems allowing for more accurate repeated surveys compared to small manned aircrafts (Watts et al. 2010). With the recent advances in lightweight camera attachments, drones can acquire high resolution images and videos. For these reasons, drones can be used in new ways to study raptors.

The use of drones to study raptors has demonstrated that some species are more tolerant of drones than others. Junda et al. (2015) observed one bird-drone collision in over 110 flights when surveying an Osprey (Pandion haliaetus) nest. The authors also noted that of the four species they surveyed, Osprey, Bald Eagle (Haliaeetus leucocephalus), Red-tailed Hawk, and Ferruginous hawk, the Osprey were the most aggressive species. The Ferruginous Hawk has the reputation of being a species that is sensitive to disturbances (White and Thurlow 1985). Recently, Nordell (2016) suggested that this reputation may be due to the disruptive methods used during the study by White and Thurlow (1985) and may not be accurate. However, Nordell (2016) notes that Ferruginous Hawks will still readily fly off nest when approached by humans on foot or in a car if approached closer than 400 m.
This investigation made use of historical data originally collected by Stan Roth from 1979–2000 to estimate Ferruginous Hawk nesting success. Stan Roth, a longtime educator and passionate biologist and conservationist, used his summer vacations to collect information on nesting Ferruginous Hawks in Kansas from 1979 to 2000. This information on historical nesting locations was provided in the form of field notes and maps by Stan Roth. Jennifer Delisle (Kansas Biological Survey), provided additional observations from a variety of sources and spanning 2000–2005. The information consisted of Roth’s efforts to document nest location, general nest size and appearance, nest occupancy, nesting success, presence of prey items, and presence of any adult Ferruginous Hawks. Over this 21 year period, a total of 111 nesting territories were documented in seven counties in western Kansas, most of which were concentrated along the Smoky Hill River valley. The data collection methods involved first consulting topographical maps for areas of canyon systems or bluff outcrops in the study area (Roth and Marzluff 1989). Roth would then hike around these locations with another researcher or with a group of high school students. Once a nest site was encountered either Roth or one of the team would climb to the nest and note the contents, nest occupancy, nest dimensions and condition. I am fortunate to have this body of work over this time span.

I used these historical data in an attempt to revisit these nest sites and evaluate the current status of breeding populations of Ferruginous Hawks relative to previous conditions. Success was limited by the scale of the area, relative accuracy of historical locality information, and changes in attitudes towards access to private property. Nests were identified throughout the breeding season, May through July, at varying stages of development, which can lead to overestimates in nest success. Unused nests or abandoned nests are more difficult to locate due to
the absence of adults. However, because Stan always revisited every nesting location to
determine fate, nest success estimations are likely accurate.

There are many ways to define nesting success in raptor studies. For this study the term
success is defined as a nest that had live young or presumed viable eggs when it was visited.
Alternatively, investigators may revisit the same nest sites throughout the breeding season. These
studies typically define a nest as successful if the young were able to be independent (Steenhof
and Newton 2007). Young hawks are usually independent 40 days after they hatch (Steenhof and
Newton 2007). Given the scope of this survey and variable nature of historic information this
protocol was simply not practical. Accordingly, I used Apparent Nest Success (ANS), to
compare historic and current nest successes. ANS is calculated by dividing the number of
successful nesting attempts by the total number of nesting attempts with a known fate and these
data were available for all survey periods.

Over the last 20 years, little research has been done on Ferruginous Hawks in Kansas.
Previous reports have indicated the highest concentration of nesting Ferruginous Hawks in the
Smoky Hill River drainage. The local habitat near each nest is primarily rangeland with 50% or
less being cropland. Their dependence on nearby prairie dog towns and grasslands results in
suggestions by some that there is a shortage of suitable breeding habitat. Overwintering
Ferruginous Hawks occur in Kansas at sites of prairie dog towns, especially those with nearby
perches. In the State of Kansas, the Ferruginous Hawk is designated as a Species of Greatest
Conservation Need, Tier II. This study was undertaken to provide updated information about the
nesting status of the Ferruginous Hawk in Kansas.
I completed several objectives for my study: 1) Evaluated the use or status of historical nesting sites; 2) Evaluated the use of small unoccupied aerial vehicles for surveying raptors; 3) Expanded survey areas outside of known historical sites to find new active nests.
METHODS

Field Sites:

Between 1979 and 2000, 111 nest sites were documented across seven counties in western Kansas as well as a number of documented sightings outside this core area (Stan Roth pers. comm. 1979–2000; Jennifer Delisle, Kansas Biological Survey, pers. comm. 2001–2005). Most of the nests were built on rocky outcrops, cliffs, rock columns or trees. The privately-owned properties where the nest sites were located were almost exclusively used for cattle ranching, with some surrounding areas of cropland. Properties with nest sites ranged in size from 80 acres to over 16,000 acres. Due to the rocky landscape in the Smoky Hill River drainage, the roads throughout this area are sparse and the majority are dirt-tracks.

Methods-Contemporary nest visits:

Attempts were made to revisit all 111 nesting territories during the summers of 2019 and 2020. The first step in this process was to determine the landowner of the property for each nesting territory. Current landowners were identified and contact information was obtained using OnXmaps, an online map service. The program allows users to upload GPS coordinates, and provides a spatial representation of the Kansas State Private Landowners and Sectional map information. In some cases, additional search of County Plat maps and the online The White Pages was necessary. These investigations identified 82 landowners where historical nests were documented. I was able to contact 62 landowners, and 54 granted permissions for surveys (eight denied access). I was unable to contact 20 landowners over the course of the study most of which were held in large land trusts.

I visited historic nest sites along with an assistant beginning in the last week of May and continuing through July in both 2019 and 2020. This timeframe ensured that we did not disturb
the hawks as they established their early nesting, while still capturing the peak of nesting activity. Depending on access, we approached each historical nest site on foot from a minimum distance of 200 m. Often hikes of one to two km were necessary at historical localities to identify new nest sites in adjacent, appropriate habitats. Survey duration varied from one to two hours when information was accurate and habitat had low complexity, and up to three days when the terrain was complex and the quality of locality information was less precise. At all nests encountered, location was recorded and occupancy was determined, as well as the presence of any other raptor species, interactions, and nests. Nests were located by searching with binoculars or a spotting scope along bluffs, rock columns or rocky outcrops. A common indicator of a nest was a pile of fallen sticks at the base of a rock face. Adult bird(s) were often present at an active nest site and would call and flush from the nest when the nest was approached.

Methods—Use of Drones to Determine Nest Contents:

At each nest site we used a Phantom 4 V2.0 (DJI) equipped with a 20 megapixel camera and DJI GO 4 software to photo-document the nest and its contents. A primary concern with the use of drones was the safety of the adult hawks and their offspring. Recent research has demonstrated that Ferruginous Hawks are tolerant of drones and will return to their nests after survey completion (Junda et al. 2015). I established a standard protocol to minimize disturbance during the breeding season and still obtain quantitative information on adults, eggs, number of young and age estimates. At active nest sites we collected videos of the immediate nest surroundings to document the surrounding habitat structure.

The operable conditions for each flight were: i) absence of potential nest predators, ii) no precipitation, iii) wind speed less than 25mph (40 km/hr), and iv) temperature between 41-98°F (5-36°C). These conditions were determined based on current publications and limitations of the
Phantom 4 Pro drone (Junda et al. 2015, DJI 2021). Two persons were present for each flight, with one person serving as the drone pilot and one serving as a spotter to track or watch for adult Ferruginous Hawks or any other birds approaching the drone. Every survey began while approaching the nest on foot in a direct fashion with constant communication between the spotter and pilot on location and behavior of adults if present. The spotter recorded the adult behavior including, at what distance flushing occurred, height of flight, and direction of flight. The pilot determined the best location for takeoff of the drone based on availability of flat and open surfaces, with takeoff occurring only once the parent bird(s) flushed from the nest. Once airborne the drone would “hover and wait” approximately three to five m above the takeoff area to ensure the aircraft was stable and responding to commands. If at any point during the flight birds reacted aggressively (by attacking the drone or surveyors), then the drone would be landed and the survey cancelled. Once the spotter confirmed the adult bird(s) were a safe distance from the nest, a survey was conducted and the spotter periodically informed the pilot of the location of adult bird(s) locations. The drone was elevated to approximately five to ten m above the nest height (when landscape and topography allowed) and then flown to the nest site. Once the drone was within five to ten m from the nest, the spotter and pilot confirmed the drone was above the nest both by line of sight and camera view. The pilot then flew directly above the nest to observe camera images in real time and take five to ten pictures, adjusting the camera angle as needed. Once quality pictures and a video were collected, the drone was quickly returned to the takeoff area to land. The pilot then powered down and disassembled the drone while the spotter noted the behavior of the adult bird(s). The age of young hawks was estimated from drone photos using the “Photographic Guide for Aging Nestling Ferruginous Hawks” published in 1985 by Marc Q. Moritsch. The age recorded was the age of the oldest nestling in days.
Methods-Transcription of Historical Data:

Journal-style accounts of visits to nesting sites from 1979–1987, 1993–1994, 1996 and 2000 were provided by Jennifer Delisle of the Kansas Biological Survey with permission from Stan Roth. I extracted and converted locality information for use in planning surveys and spatial analysis in ArcGIS. In addition, I summarized nest use over the historical survey period and breeding success. These data included: visit date, nest presence, nest occupancy, nest success, if eggs/young were present in the nest, number of eggs/young, age of oldest young, hatch date (calculated by subtracting the age of young from the visit date), number of adults present at nest site, and latitude and longitude of the nest that year. Data also included the historical and contemporary site identification codes, the latitude and longitude of where the nest was first located, and the years in which a new active nest was found at a different location than last year in the nesting territory (FEHA_Historic_and_Current_Nest_Survey_Info.xlsx).

Subsequently, these data were divided into temporally discrete blocks, and variables were averaged within blocks in an attempt to better elucidate historical trends in breeding success and habitat associations. The blocks of time are as follows: 1979–1981, 1982–1984, 1985–1987, 1993–2000 (including years 1993, 1994, 1996, 2000), and 2019–2020. Nest presence, nest occupancy, nest summary, number of eggs/young, and adult presence were both summed and averaged, within each of the five timeframes. Other totals included: sum of years present, sum of years active, sum of years successful, sum of years surveyed, the last year the nest was present, the last year the nest was active, the last year the nest was successful and the number of years the nest moved locations.
Methods – Spatial Analysis and Databases:

ArcMap (version 10.8.1) was used to elucidate spatial patterns in the distribution of nesting sites over time and in association with land use, including developments of oil wells in nesting territories, wind turbine locations, and land cover. Unless otherwise stated all data were obtained from the Kansas Data Access and Support Center (DASC March 3, 2021) database.

The most recent land cover data were available for 2015. The data were collected by the USGS and the Kansas Biological Survey and estimates land use and land cover as polygons based on the Anderson classification system, and the primary cover types were Agriculture and Rangeland. Agriculture compromises land that is used for food or fiber production, including croplands, orchards, and feeding operations. Rangeland is defined as land where the majority of vegetation is grasses, forbs or shrubs (Anderson 1976). The proportion of land cover type was calculated from the number of 30 x 30 m areas (pixels) categorized as Rangeland or Agriculture divided by the total number of 30 m x 30 m units within a 0.5 mi. radius of each nest site. Average slope was calculated within 0.25 mi. radius of all nest sites and calculated by determining the mean of the slope values from each 30 m x 30 m area (pixel) within a 0.25 mi. radius of a nest location.

Prairie dog distributions and size of colonies were estimated from recent NAIP images available for 2015 (Oriez 2020). The average distances to nearest prairie dog colony were calculated by determining the mean of the distances from each 30 m x 30 m area (pixel) within a 0.5 mi. radius of a nest location.

The potential influence of anthropogenic factors was estimated by calculating the average distance to oil wells, wind towers, gravel roads and paved roads. The average distances were calculated by determining the mean of the distances from each 30 m x 30 m area (pixel)
within a 0.5 mi. radius of a nest location. Variables that represented energy extraction activity included GPS location of oil wells, date of first drilling, date of last drilling, and volume of production in the survey area. Oil wells were mapped and layers were made of new oil wells in the five survey timeframes. Emphasis was placed on wells constructed during the breeding season (March–July) and within a one mi. radius of the nest sites. Similarly, the average distance to gravel roads and paved roads was estimated. The locations of wind towers were plotted along with the nest locations but no wind towers occurred within 10 mi. (16 km) of the nearest nest site and so were not included in further evaluations.

In an attempt to understand the compounding nature of multiple habitat influences and potential for a limited number of suitable nesting sites I developed a map of five variables associated with Ferruginous Hawk nesting. These variables were determined to be important after mapping them individually in relation to Apparent Nest Success (ANS) values, comparing data from successful, active and inactive nest sites from 2019 and 2020, and multiple literature sources (Bechard et al. 1990, Datta 2016, Diffendorfer et al. 2021, Gilmer and Stewart 1983, Giovanni et al. 2007, Keeley et al. 2015, Leary et al. 1998, McConnell et al. 2008, Nordell 2016, Paprocki et al. 2015, Roth and Marzluff 1989, Schmutz 1987, Wallace et al. 2016, Wiggins et al. 2017).

Determining the distance to the nearest Black-tailed prairie dog colony was challenging. Data collected in 2015 was the most recent Black-tailed prairie dog information available. To account for the differences in time between prairie dog data collection and Ferruginous Hawk nesting status collected in 2019 and 2020, only colonies greater than 37 acres (colonies likely to persist) were included (Lomolino et al. 2004, Oriez 2020). In addition, oil well construction during and outside of breeding season, distance to road and road type, slope of the landscape
within 0.25 mi. of nests, and Rangeland cover within 0.5 mi. nest sites were estimated. Values between 0 (low) and 3 (high) were assigned based on a review of the frequency distribution of relative nest success against each variable. ArcMap, was used to develop a “heat map” that spatially represented the distribution of nest sites and their relative success across the core survey area.

**Methods-Surveys for wintering Ferruginous Hawks**

In addition to surveying breeding Ferruginous Hawks, I also conducted surveys of Ferruginous Hawks overwintering in the core area during the months of November to January in 2020 and 2021. Seven distinct routes were designed that passed through majority grassland habitats throughout the core area of Logan, Gove, Trego, Lane and Scott counties. Wallace county was not visited during these surveys for lack of easily navigable roads and distance from Hays, KS. Each route was surveyed at least twice, in most cases by a survey team of two people, one driver and one spotter. Most surveys consisted of driving on highways from Hays to the start of the routes, which were most often dirt or gravel roads. While driving on dirt roads the car speed was kept at 25 mph or less. Any bird of prey seen by the driver or passenger was identified, if possible. The materials used for identification included a spotting scope and car mount, binoculars and any bird calls heard. When a Ferruginous Hawk was detected then information was captured on a worksheet. Information recorded included: date, route number, observer initials, number of birds seen, the GPS coordinates, perch type, if the bird was seen while driving or walking, the time of observation and any other comments.
RESULTS

In late 2019 and early 2020, I extracted nesting locality and relative nest success information from field notes and maps that spanned 21 years from 1979 to 2000. These materials documented 111 nesting sites of Ferruginous Hawks and defined a core breeding region. (Figure 1; Table 1; Appendix 1). From May through July of 2019 and 2020 I revisited 94 of these sites and documented nest success and breeding activity. In addition, attempts were made to identify documented sightings and putative nest sites in southwestern and extreme northwestern Kansas (Figure 1). I did not document any sightings or breeding activity at sites south of the Smoky Hill watershed. I was unable to gain access to historic locations in extreme northwestern Kansas. During 2019 and 2020 a total of 56 drone flights were performed and no Ferruginous Hawks reacted aggressively to their presence. Over all flights the average flight time was 6m 6s. The most challenging aspect in regards to drone flights was the range of acceptable conditions for wind speed and temperature, as western Kansas in summer can be both quite windy and hot.

I divided the entire survey time period (1979–2020) into five timeframes to summarize information and modulate the different levels of effort across the 40 year timeframe (Tables 1 and 2). During 2019 and 2020 I visited on average fewer sites than in the first four timeframes and documented fewer successful nests, adult birds, and eggs/young (Table 1). Nonetheless, I was able to revisit most sites over the 2-year period such that average values by timeframe for indicators of breeding success were more similar in magnitude but exhibited declines across periods (Table 2). Of particular note are consistent declines in the average number of successful nests and the average number of eggs/young per nest searched. Nest sites were primarily clustered within Wallace, Logan, Gove, Trego, Scott, and Lane counties (Figure 1), which formed the core area for nest surveys and breeding success. The number of nests that were
successful on average declined from 37 to 25 in the first four timeframes and still further to nine on average during this investigation (Figures 2–9 and Table 2). Spatially, the distribution of successful nests contracted from the east and west over the five timeframes, but most dramatically in the last 20 years, to a core density in western Gove and eastern Logan counties.

I extracted values for individual habitat variables to explore relationships with nest success in the core area. These variables included proximity to prairie dog colonies, grassland cover, oil well activity, and disturbance from roads. I explored relationships between these values for each nest location and apparent nest success (ANS) for nest sites surveyed in 2019 and 2020. ANS (see Appendix 1) varied widely across active, inactive, and successful nests in relation to the majority of these variables (Figures. 7–14).

Ferruginous Hawk nest sites were typically located in areas with a 0.50 or higher proportion of grassland cover within a 0.5 mi. radius of the nest. Most successful nests were in areas with a proportion greater than 0.70 of grassland surrounding the nest and an average slope greater than three (Figures 7–8). In addition, the majority of nest sites were within an average distance of 10 mi. from a prairie dog colony. However, all successful nests were within an average distance of 2.5 mi. (Figure. 9).

Ferruginous Hawk nest sites were in close proximity to oil wells (Figures 10–12). Nests were within an average distance of three mi. of an active oil well, within 10 mi. of newly built oil wells, and successful and inactive nest sites were uniformly distributed in these cases (Figures 11–12). However, all successful nests were an average distance of over two mi. from oil wells constructed during the breeding season (Figure 10).
The distance of nest sites to gravel and paved roads varied widely and no pattern of successful versus inactive nests was apparent in relation to gravel roads (Figure 13). However, all successful nests were greater than two miles from paved roads (Figure 14).

I also attempted to visualize the collective influence of these variables within the complex landscape of the core breeding area (Figure 15). Estimates of these variables were used to construct habitat index values (Table 3), which were mapped across the core area and associated with the ANS of nest sites surveyed in 2019 and 2020. Nests within the core, including all of the successful nests, were typically located in areas with higher cumulative scores that comprise the habitat index (Figure 16). I also grouped nests into relative success index categories and mapped them in relation to landcover type. Most nests, regardless of success index value, were in grassland areas (Figure 17). Low scores appear to be concentrated within more fragmented rangeland landcover.

One interesting and noticeable change seen in the historical data was a reduction in the average hatch date. The hatch date was calculated by subtracting the age of the young from the survey date whenever age was included by Stan Roth. Studies have shown evidence that global changes to climate have altered natural courses of many birds’ annual events. Many bird species, even some hawks, have begun egg-laying and nesting earlier in the year (Rosenfield et al. 2017). However, this reduction in average hatch date could be due to inaccurate aging of young hawks by Stan Roth during the years of 1979 to the late 1980’s. Roth noted that he started to use Moritsch’s Photographic Guide to Aging Nestlings of Ferruginous Hawk (published in 1985) as early as 1987. As there is a noticeable reduction in the average hatch date starting at the 1987 timepoint, I believe the use of the ageing guide is very likely be the cause of the changing average hatch date.
Throughout Roth’s surveys the number of adults present at the nest site is consistent with the number of successful nests. However, the values of adult Ferruginous Hawks present at nest sites for 2019 and 2020 are not comparable due to differences in survey methods. Roth’s methods typically involved one or more people climbing to nest sites and he often noted being dive-bombed by parent hawks during this process or during the survey. We had no such occurrences and a minimum distance of 25m from the nest was adhered to by technicians. This gives further evidence that the use of drones for documenting nest success and other observations is less disruptive than traditional methods.

Finally, I attempted to assess wintering Ferruginous Hawk numbers by surveying routes that were established within the core nesting area, though this was not a central component to our study. Effort and species observed during these surveys are summarized in Table 4.
DISCUSSION

As a major component of this investigation, I had access to a treasure trove of historical information and so I am indebted to Stan Roth for his work and generosity in sharing this information. Nonetheless, working across a 40-year time span necessarily results in challenges in attempting to accurately compare data formats that were collected for one purpose and relating them to another. I attempted to be conservative with our approach particularly as I endeavored to associate historical breeding success to contemporary finer-scaled habitat information. The association of this type of information is fraught with historical inertia that makes a one-to-one association of breeding success at a location or nest site over a 40-year period to current landcover information inherently challenging. It would be reckless to assume that landcover and other development in this landscape had not changed in that time period. As such, I did not attempt to correlate or regress nest sites to habitat variables but rather emphasized general patterns of current nest success and habitat variables. Accordingly, I have limited these types of interpretations to sites visited in the current study, and associated nest success to these recent habitat variables in the landscape.

I revisited historical Ferruginous Hawk nest sites and used drones to identify nests, their locations, and their contents. In doing so, I provide the first updated status report on the breeding populations of Ferruginous Hawks in Kansas in two decades. By comparing the historical series of nesting surveys to our surveys, I documented that Ferruginous Hawk nest occupancy and successful nesting have dramatically decreased as judged by 1) the contraction of successful nest sites to a more confined core in Gove and Logan counties (Figures 2–6) and 2) a decrease in all of the variables associated with breeding success that I quantified (Table 2). The most precipitous declines have apparently occurred within the last 20 years (Table 2).
I noted a steady decline in the percent of nests searched that were successful across the five timeframes from 54.4% to 19.1% of nests successful. Having on average fewer than 10 successful nests per year should be a cause for concern. Furthermore, the average number of eggs or young per nest searched also decreased across timeframes from 1.43 during the first timeframe to just 0.38 during the most recent timeframe. There are several factors that may have contributed to these declines in Ferruginous Hawk nesting activity and success in western Kansas. I evaluated compounding influences including landscape characteristics, proximity to prairie dogs, and anthropogenic disturbance.

Landscape cover as grassland / rangeland and proximity to prairie dogs were both associated with Ferruginous Hawk nesting activity and success. Successful nests were frequently located in areas with relatively high rangeland landcover (70%). Rangeland areas are more likely to have limestone outcrops that Ferruginous Hawks use for nesting in the Smoky Hill River valley in Kansas, and are likely to sustain appropriate food resources for raptors. Prairie dogs are known to be a major prey item for Ferruginous Hawks. Although there were fewer nests in 2019 and 2020, most of them were in relatively close proximity to prairie dog colonies (within two miles).

Active oil wells did not appear to negatively affect Ferruginous Hawk nesting activity, however successful nests were greater than two miles from new well construction during the breeding season. I suspect that the locations suitable for oil well construction are also suitable for Ferruginous Hawk nesting sites. Some studies have suggested that oil and gas developments may improve habitat for prey by increasing edge habitats (Keough & Conover 2012, Zelenak & Rotella 1997). However, many other studies found similar results to our study, of successfully nesting Ferruginous Hawks unbothered by oil well development (Wallace et al. 2016, Keough &
Conover 2012, Zelenak & Rotella 1997). Nevertheless, the Ferruginous Hawk is known as a sensitive species there is a limit to the level of tolerable disturbances (Schmutz 1989, White & Thurow 1985). Currently some successful Ferruginous Hawk nesting seems to be able to continue with the present level of oil and gas development in western Kansas.

Ferruginous Hawks did not appear to be affected by proximity of roads to their nesting sites. Presumably, automobile traffic on paved and gravel roads in the core area is minimal. Similar studies have shown little to no influence of roads on nesting success of Ferruginous Hawks in Wyoming and Idaho (Wallace et al. 2016, Coates et al. 2014, White & Thurlow 1985).

Attempts to visualize these potential influences on breeding success reveal that at least based on the conservative habitat indexing reported here, there is likely more available breeding habitat in the core area than was being used in 2019 and 2020 (Figure 16). Likewise, when apparent nest success (ANS) scores were overlain on land cover, arguably successful nests tended to occur in more contiguous blocks of rangeland and there appear to be blocks of rangeland that are not being used successfully.

Prairie dog declines due to deliberate eradication might be influencing the decline in Ferruginous Hawk nesting activity and success. Fewer Ferruginous Hawks attempting to nest in western Kansas might be due to reduced food resources. The consistent reduction in nesting success but more importantly fewer eggs or young per nests searched on average strongly suggests a lack of prey resources to support larger numbers of offspring. Anecdotally, the loss of what was a successful series of nests in Wallace County coincided with a focused eradication of prairie dogs in that area (Stan Roth pers. comm.). In addition, the contraction of the core breeding area in Gove and Logan counties overlaps the largest contiguous prairie dog complexes in the region (Oriez 2020). Though beyond the scope of this study, the prey base might not
support the energetic costs of nesting and so breeding pairs might defer year to year or avoid the region altogether. Regardless, fewer offspring imprinting on the region may make it less likely for Ferruginous Hawk populations to sustain themselves or increase.

Decline in prey species has a large impact on the successful breeding of large raptor species (Howard & Wolfe 1976, Woffinden & Murphy 1977, 1989). Because they are large in body size, Ferruginous Hawks rely on relatively large mammalian prey of prairie dogs, jackrabbits, gophers and ground squirrels (Cartron et al. 2004, Keeley et al. 2016, Gilmer & Stewart 1983). Ferruginous Hawk nesting success seems to be influenced by major declines in prey species (Howard & Wolfe 1976, Woffinden & Murphy 1977). Evidence shows that once prey populations increase after a population crash, Ferruginous Hawks can still be slow to resume nesting activity in the area. In order to retain Ferruginous Hawks in Kansas it is vital to allow for the persistence of black-tailed prairie dogs in their core nesting area.

Considerations for other possible habitat variables or disturbances known to influence the nesting behaviors of other birds of prey included water accessibility and windmill farms (Diffendorfer et al. 2021, Wiggins et al. 2017, Bechard et al. 1990). The closest windmill farms to historic nesting sites were over 10 miles away. The distance of windmill farms to nesting sites was apparently not an important factor for Ferruginous Hawk nesting in our study. Other studies have shown a decrease in raptor abundance following windfarm constructions (Garvin et al. 2011). It has been suggested that windfarms are problematic for many different birds of prey, with Ferruginous Hawks having a high level of potential population-impacts (Diffendorfer et al. 2021, Eichhorn et al. 2012). In order for Ferruginous Hawk nesting success to continue in western Kansas, there must be a lack of any future wind farm production in the core nesting area.
I also investigated the distance of nest sites to water sources, including Smoky Hill River, streams, playas and wetlands. Western Kansas during the breeding season can be very dry with somewhat frequent storms including high winds, rain and hail. There were no differences seen between nesting success, ANS values and distance to nearest water source.

Other studies on Ferruginous Hawks and raptors have shown improved nesting success on artificial nesting platforms (Wallace et al. 2016, Gilmer & Stewart 1983). Many of these studies are conducted in areas similar to western Kansas, with vegetation dominated by rangeland and agriculture. However, many of these areas lack an ample amount of naturally elevated safe nesting sites. In our study area the Smoky Hill Chalk formations, found throughout Logan and Gove counties and in Northern Scott and Lane counties, were almost exclusively used as nesting locations. Due to the abundance of these naturally occurring geologic formations, it is likely that the use of artificial nesting platforms in western Kansas is unnecessary as long as the chalk formations remain undeveloped and undisturbed during the breeding season.

This study would not have been possible without the ability to safely and efficiently use drones to perform nest surveying. A minimal amount of research so far has been performed on birds of prey using drones (Rodríguez et al. 2012, Junda et al. 2015, Potapov et al. 2013, Canal & Negro 2018). The successful use of drones in this research will hopefully allow for more possibilities for other researchers to use similar methods.

Recommendations and Conclusions

Conservation efforts should prioritize preservation of appropriate habitat and food resources for Ferruginous Hawks. To that end, providing landowners with support for rangeland preservation may be beneficial to avoid further fragmentation and reduction of these areas that
support sensitive raptor species. Conservation efforts should also emphasize education about and support for prairie dogs, due to their utility as a food resource for Ferruginous Hawks and other large raptors. Cooperative landowner incentive programs across natural resource agencies at both the state and federal levels will likely be most effective. Lastly, oil well construction in rangelands should be avoided during the breeding season, which is an especially sensitive time for Ferruginous Hawks.

Based on our findings, I recommend that future research on Ferruginous Hawks in Kansas focus on searching areas with sufficient rangeland and areas near prairie dog colonies. In particular, future research could attempt to collect updated information on prairie dog locations and population sizes in western Kansas. These data coupled with data on the magnitude of changes in suitable breeding habitat in Kansas may help to elucidate specific causes of Ferruginous Hawk declines.

Our study demonstrated that, when used appropriately, drones can enhance data collection for raptor surveys with minimal disturbance. It is necessary to have two observers for drone surveys: a pilot to operate the drone and a spotter to observe hawk behavior and to help determine if a flight should be stopped due to disturbance. Future studies using drones to study Ferruginous Hawks should follow our protocol, or one that is similar, to ensure safety of the birds, drone pilot, and spotter.

Our findings provide evidence that breeding activity of Ferruginous Hawks has declined significantly in Kansas over the last 40 years. Declines in successful nests to fewer than 10 on average and a substantive decline in the number of young raised in a once extremely productive area are causes for grave concern. I attribute these declines to a reduced amount or fragmentation of rangeland habitat and loss of prairie dog colonies in the landscape. Preservation of habitat and
prey base are actions that appear to have the highest probability of reversing declines.

Partnerships between natural resources agencies and private landowner will be necessary to successfully conserve breeding populations of Ferruginous Hawks in Kansas.
LITERATURE CITED


JOYCE, K.E., K. ANDERSON and R.E. BARTOLO. 2021. Of Course We Fly Unmanned—We’re Women! Drones 5: 21.


Nordell, C.J. 2016. Ferruginous Hawk (Buteo regalis) responses to human disturbance during the breeding season: 97.


Table 1. Total numbers of nests searched, nests present, active nests, successful nests, eggs or young in nests, and adults present across the five timeframes.

<table>
<thead>
<tr>
<th>Timeframe Years</th>
<th>Years Included</th>
<th>Total Nests Searched</th>
<th>Total Nests Present</th>
<th>Total Nests Active</th>
<th>Total Nests Successful</th>
<th>Total Number of Eggs/ Young</th>
<th>Total Adults Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019-2020</td>
<td>2019, 2020</td>
<td>94</td>
<td>35</td>
<td>23</td>
<td>17</td>
<td>35</td>
<td>25</td>
</tr>
</tbody>
</table>
Table 2. Average values by year of numbers of nests searched, nests present, active nests, successful nests, eggs or young in nests, and adults present as well as percent of nests searched that were successful, and average number of eggs or young per nest searched across the five timeframes.

<table>
<thead>
<tr>
<th>Timeframe Years</th>
<th>Years Included</th>
<th>Average Nests Searched</th>
<th>Average Nests Present</th>
<th>Average Nests Active</th>
<th>Average Nests Successful</th>
<th>Average Number of Eggs/ Young</th>
<th>Average Adults Present</th>
<th>Percent of Nests Searched that are Successful</th>
<th>Average Number of Eggs/ Young per nest Searched</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982-1984</td>
<td>1982, 1983, 1984</td>
<td>85</td>
<td>83</td>
<td>43</td>
<td>33</td>
<td>81</td>
<td>68</td>
<td>38.8%</td>
<td>0.95</td>
</tr>
<tr>
<td>1985-1987</td>
<td>1985, 1986, 1987</td>
<td>98</td>
<td>92</td>
<td>45</td>
<td>32</td>
<td>76</td>
<td>70</td>
<td>30.2%</td>
<td>0.77</td>
</tr>
<tr>
<td>2019-2020</td>
<td>2019, 2020</td>
<td>47</td>
<td>18</td>
<td>12</td>
<td>9</td>
<td>18</td>
<td>13</td>
<td>19.1%</td>
<td>0.38</td>
</tr>
</tbody>
</table>
Table 3: Scoring system to construct habitat index values based on variables that are likely influence Ferruginous Hawk nesting. Scores range from 0 to 3.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Well Construction and Proximity</td>
<td>3: All active oil wells over one mile from the nest site. No new oil wells constructed within three miles from the nest site.</td>
<td>Newly built oil wells are the most disturbing to nest site usage. Disturbances during the construction would include multiple trucks, many people coming and going for potentially two to four months (Wiggins et al 2017). Also, active oil wells need to be checked frequently and tanks are regularly emptied, both of which involve trucks driving to oil pumps and storage tanks.</td>
</tr>
<tr>
<td></td>
<td>2: Active oil well less than one mi from nest site or newly constructed oil well btw three-one mi. from nest.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1: Newly constructed oil well between one mi. and three mi. from nest sites during breeding season, or newly constructed oil well (not during breeding season)less than one mi from nest.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0: Newly constructed oil well less than one mi. from nest sites during breeding season.</td>
<td></td>
</tr>
<tr>
<td>Road Proximity</td>
<td>3: Over two mi from paved and over one mi. from gravel roads.</td>
<td>Gravel roads do not seem to bother FEHA nest sites (See Logan #33). Nests tend to be farther away from paved roads, as paved roads in this area make up highways and town streets.</td>
</tr>
<tr>
<td></td>
<td>2: Within one mi from gravel roads, over two mi. from paved roads.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1: Between one and two mi. from paved roads.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0: Less than one mi. from paved roads.</td>
<td></td>
</tr>
<tr>
<td>Land Cover in the area within a one mi radius of nest site</td>
<td>0: Less than 50% of area is rangeland.</td>
<td>Landscapes with moderate coverages (&lt;50%) of cropland and hayland are used for nesting and foraging (Blair 1978; Wakeley 1978; Gilmer and Stewart 1983; Konrad and Gilmer 1986; Schmutz 1989, 1991a; Bechard et al. 1990; Faanes and Lingle 1995; Leary et al. 1998).</td>
</tr>
<tr>
<td></td>
<td>1: Between 50-75% of area is rangeland</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2: Between 75-100% of area is rangeland</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3: Over 75% of area is rangeland and there are rocks present</td>
<td></td>
</tr>
<tr>
<td>Variable</td>
<td>Value</td>
<td>Justification</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Slope of area immediately surrounding nest site (radius quarter mile)</td>
<td>0: Slope of area surrounding nest is between 0-1.0</td>
<td>Roth and Marzluff 1989-Rated nest sites by their accessibility to quadrupedal predators. The majority (70%) were moderately hard or impossible. This information combined with the information about FEHA nests on rocks are a good representation of slope.</td>
</tr>
<tr>
<td></td>
<td>1: Slope of area surrounding nest is between 1.0-2.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2: Slope of area surrounding nest is between 2.0-4.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3: Slope of area surrounding nest is above 4.0</td>
<td></td>
</tr>
<tr>
<td>Prairie Dog Town Proximity</td>
<td>0: Over 10 km from a Prairie dog town at least 37 acres in size</td>
<td>Prairie dogs are a major prey source for FEHA in the Great Plains. The locations and persistence of prairie dogs need to be considered in the management of FEHA (Giovanni et al. 2007, Ng 2021, Woffinden &amp; Murphy 1977) FEHA were often seen hunting at distances of 10km (Leary et al. 1998). Most FEHA nests were found within eight km of Prairie dog colonies (Roth &amp; Marzluff 1989).</td>
</tr>
<tr>
<td></td>
<td>1: Between 10 km and eight km from a Prairie dog town at least 37 acres in size</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2: Between eight km and three km from a Prairie dog town at least 37 acres in size</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3: Three km or less from a Prairie dog town at least 37 acres in size</td>
<td></td>
</tr>
</tbody>
</table>
Table 4: Total hours spent performing winter Ferruginous Hawk surveys and total hours spent driving to and from winter survey routes. Also, total amount of Ferruginous Hawks, Prairie Falcons and Golden Eagles seen during all surveys.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Hours Performing Survey Routes</td>
<td>32 hours: 57 min</td>
</tr>
<tr>
<td>Total Hours Driving to and from Survey Routes</td>
<td>42 hours: 31 min</td>
</tr>
<tr>
<td>Total Ferruginous Hawks Seen</td>
<td>8</td>
</tr>
<tr>
<td>Total Golden Eagles Seen</td>
<td>9</td>
</tr>
<tr>
<td>Total Prairie Falcons Seen</td>
<td>10</td>
</tr>
</tbody>
</table>
Figure 1. Historic nest sites for Ferruginous Hawks (1979 – 2000) and identification of core nesting area.
Figure 2. Nest sites surveyed during 1979, 1980 and 1981. Successful nests (green circles) contained either eggs or young. Active nests (red circles) occurred where nesting attempts were made. Inactive nests (black circles) were historic locations with no activity or the nest could not be found. White circles indicate historic nest sites that could not be visited.
Figure 3. Nest sites surveyed during 1982, 1983 and 1984. Successful nests (green circles) contained either eggs or young. Active nests (red circles) occurred where nesting attempts were made. Inactive nests (black circles) were historic locations with no activity or the nest could not be found. White circles indicate historic nest sites that could not be visited.
Figure 4. Nest sites surveyed during 1885, 1986, and 1987. Successful nests (green circles) contained either eggs or young. Active nests (red circles) occurred where nesting attempts were made. Inactive nests (black circles) were historic locations with no activity or the nest could not be found. White circles indicate historic nest sites that could not be visited.
Figure 5. Nest sites surveyed during 1993, 1994, 1996 and 2000. Successful nests (green circles) contained either eggs or young. Active nests (red circles) occurred where nesting attempts were made. Inactive nests (black circles) were historic locations with no activity or the nest could not be found. White circles indicate historic nest sites that could not be visited.
Figure 6. Nest sites surveyed during 2019 and 2020. Successful nests (green circles) contained either eggs or young. Active nests (red circles) occurred where nesting attempts were made. Inactive nests (black circles) were historic locations with no activity or the nest could not be found. White circles indicate historic nest sites that could not be visited.
Proportion of grassland in surrounding 1 mi radius of nest site

Figure 7. Relationship between Apparent Nest Success and the proportion of grassland within a 0.5 mi. radius around the nest sites surveyed in 2019 and 2020.

Active nests - sites nesting attempt.

Inactive nests – historic nest site but with no activity.

Successful nests - nests with eggs or young present at the time of the survey.

Figure 8. Relationship between Apparent Nest Success and mean slope surrounding the nest in a 0.25 mi radius around the nest sites surveyed in 2019 and 2020.

Active nests - sites nesting attempt.

Inactive nests – historic nest site but with no activity.

Successful nests - nests with eggs or young present at the time of the survey.
Figure 9. Relationship between Apparent Nest Success and mean distance to nearest prairie dog colony (mi.) for the nest sites surveyed in 2019 and 2020.

Active nests - sites nesting attempt.

Inactive nests – historic nest site but with no activity.

Successful nests - nests with eggs or young present at the time of the survey.

Figure 10. Relationship Apparent Nest Success and the distance to the nearest oil well that was newly built during the breeding season (mi) for the nest sites surveyed in 2019 and 2020.

Active nests - sites nesting attempt.

Inactive nests – historic nest site but with no activity.

Successful nests - nests with eggs or young present at the time of the survey.
Figure 11. Relationship between Apparent Nest Success and the distance to the nearest active oil well (mi) for the nest sites surveyed in 2019 and 2020.

*Active* nests - sites nesting attempt.

*Inactive* nests – historic nest site but with no activity.

*Successful* nests - nests with eggs or young present at the time of the survey.

Figure 12. Relationship between Apparent Nest Success and the distance to the nearest newly built oil well (mi) for the nest sites surveyed in 2019 and 2020.

*Active* nests - sites nesting attempt.

*Inactive* nests – historic nest site but with no activity.

*Successful* nests - nests with eggs or young present at the time of the survey.
Figure 13. Relationship between Apparent Nest Success and the distance to the nearest gravel road (mi) for the nest sites surveyed in 2019 and 2020.

Active nests - sites nesting attempt.

Inactive nests – historic nest site but with no activity.

Successful nests - nests with eggs or young present at the time of the survey.

Figure 14. Relationship between Apparent Nest Success and the distance to the nearest paved road (mi) for the nest sites surveyed in 2019 and 2020.

Active nests - sites nesting attempt.

Inactive nests – historic nest site but with no activity.

Successful nests - nests with eggs or young present at the time of the survey.
Figure 15. Spatial representation of the historic core breeding area of Ferruginous Hawks in Kansas and the distribution of landscape features and anthropogenic influences have been cited as affecting the use of habitat or nesting success. Nest sites surveyed during 2019 and 2020 are coded as: Successful nests (green circles) contained either eggs or young. Active nests (red circles) occurred where nesting attempts were made. Inactive nests (black circles) were historic locations with no activity or the nest could not be found. White circles indicate historic nest sites that could not be visited.
Figure 16. Spatial representation of the historic core breeding area of Ferruginous Hawks in Kansas and the distribution of habitat index scores as defined in Table 3. Higher scores and presumable higher quality habitat are represented by the darker colors. Nest sites surveyed during 2019 and 2020 are coded as: Successful nests (green circles) contained either eggs or young. Active nests (red circles) occurred where nesting attempts were made. Inactive nests (black circles) were historic locations with no activity or the nest could not be found. White circles indicate historic nest sites that could not be visited.
Figure 17. Spatial representation of the historic core breeding area of Ferruginous Hawks in Kansas and the distribution of landcover types (DASC). Dominant land covers are Rangeland (green) and Cropland (tan). Nest sites surveyed during 2019 and 2020 are color coded into three categories based on the frequency of Apparent Nest Success values. The nest sites with the overall highest scores are represented by green circles followed by yellow circles and the lowest values are depicted with red circles.
<table>
<thead>
<tr>
<th>Name</th>
<th>Area</th>
<th>Latitude</th>
<th>Longitude</th>
<th>PropGrassland_F</th>
<th>Rock</th>
<th>GrasslandCoreIndex</th>
<th>GravelMinDist_Mi</th>
<th>PavedMinDist_Mi</th>
<th>Date</th>
<th>Temperature</th>
<th>Wind</th>
<th>Rain</th>
<th>Humidity</th>
<th>Evapotranspiration</th>
<th>Precipitation</th>
<th>Snow</th>
<th>Condition</th>
<th>Notes</th>
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<tbody>
<tr>
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