

Chapter 14

Avian Predators in Rangelands



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Abstract Management of avian predators in western rangelands is uniquely challenging due to differences in managing for/against particular species, management of sensitive prey species, long-standing human/wildlife conflicts, and the unique legal protections within this ecological group. In general, many avian predator species considered rangeland specialists have been declining due to habitat loss, fragmentation, human sensitivity, and direct persecution. Conversely, avian predators that are more human-tolerant and/or are subsidized by human activities are significantly increasing across rangelands. The complicated nature of inter- and intra-species guilds, coupled with human dynamics has created a challenging scenario for both management for avian predators, as well as their prey. Human-mediated population control, both legal and illegal, continues for avian predators to reduce livestock conflict, aid sensitive prey populations, and/or because of general predator persecution. Conversion of rangeland to development for energy, cultivation, and urbanization remains the largest impediment to maintaining viable, historical assemblages of avian predators. Large-scale habitat protections, reduction of invasive plants, and reducing wildfire will continue to enhance at-risk populations of predators and their prey. Further, mediating human-induced mortality risks will also aid at-risk predator populations, such as reducing direct killing (poisoning and shooting), secondary poisoning from varmint control and lead ammunition use, electrocutions, and vehicle strikes, while reducing anthropogenic subsidies can help curtail population expansion of corvids. Additional understanding of long-term, successful predator control efforts for corvids and mitigation options for declining raptors is needed to help balance the avian predator–prey dynamic in western rangelands.

Keywords Anthropogenic · Avian predators · Buteo · Corvid · Eagle · Raptor · Rangeland · Raven

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14.1 General Life History and Population Dynamics

Avian predators have often been considered flagship or umbrella species due to their large home ranges and unique legal protections (Sergio et al. 2006; Donazar et al. 2016). However, the complex anthropogenic and ecological relationships of avian predators in rangeland habitats have varied drastically through history and continue to shift. The diverse migratory strategies and intra- and inter-specific competition among avian predators can impact community dynamics of raptors (hawks, eagles, and owls), corvids (ravens, crows, and magpies), and gulls in rangeland systems. Further, raptors and corvids are unique among rangeland wildlife because of their varied and complicated relationship with humans, largely due to their influence on economic interests, development, historical and contemporary persecution, conflicting multi-species management goals, and multiple legal protections.

Community composition and abundance of avian predators across rangelands are affected by inter- and intra-specific competition (Craighead and Craighead 1969), habitat quality (e.g. Dunk et al. 2019), and species-specific habitat associations. Most raptors of rangelands have evolved behaviors or traits to help facilitate hunting, movements, and breeding in open landscapes. Specialist species like the semi-fossorial burrowing owl (*Athene cunicularia*) are unique by relying on burrows excavated by mammals, such as prairie dogs and ground squirrels for nesting. As such, they have co-evolved with those species to the point where they use and rely on prairie dog alarm calls to alert them to potential predators (Bryan and Wunder 2014). Other raptors relying on open rangelands, like ferruginous hawks (*Buteo regalis*) and golden eagles (*Aquila chrysaetos*) have evolved traits including ground nesting, morphology and flight dynamics for aerial foraging, and increased sensitivity to human disturbance. There is a wide range of population trends for various species, largely based on tolerance and reliance on anthropogenic features across rangelands. Species like common ravens (*Corvus corax*) have largely increasing populations due to reliance on anthropogenic subsidies for nesting and foraging while other species like golden eagles are becoming increasingly at risk. There is also a large seasonal component to these dynamics driven by differences in migration strategies among species. Some groups exhibit prey-based partitioning, with different species occupying the same habitats but selecting differential prey (e.g., American kestrels *Falco sparverius* and red-tailed hawks *Buteo jamaicensis*). Others avoid competition by timing, either diurnal/nocturnal or by season (e.g., great horned owls *Bubo virginianus* and red-tailed hawks).

14.1.1 Nesting

Almost all avian predators are highly territorial during nesting. Those species that cannot avoid competition through prey or temporal niche partitioning can exhibit significant territoriality, or habitat partitioning (Restani 1991; Kennedy et al. 2014).

This is classically apparent within raptor species, where territorial pairs aggressively defend breeding territories from conspecifics (Newton 2010). Notably, there are some exceptions with corvids. Territorial common ravens are similar in that they aggressively defend breeding areas from conspecifics but differ by allowing non-breeding conspecifics within a territory when a food bonanza (e.g., large carcass) occurs (Webb et al. 2012). Because larger raptors can also prey on smaller raptor species, habitat partitioning in rangelands not only is a result of prey availability but also intra-guild predator–prey dynamics. This regular territoriality in avian predators, coupled with the relative ease of locating large raptor stick nests, has led to largely nest-centric management practices across rangelands, with various sized protection buffers placed around most raptor nests for disturbances during the breeding season (USFWS 2022).

Generally, raptors and corvids are k-selected species, with relatively slow reproductive rates (Newton 2010). For example, golden eagles typically do not begin reproducing until ≥ 5 years of age and breeding pairs produce an average of < 1 fledgling per year (Katzner et al. 2020a, b). This slow reproductive rate, coupled with prey or habitat specialization, has led to many raptor species' declines. While popular perception is often that breeding raptors “mate for life,” this theory is a bit misleading. Many avian predators do have high territory and mate fidelity, which can often lead to increased lifetime reproductive success (Leon-Ortega et al. 2017), but some studies suggest that individual quality is a better driver of reproductive success than territory quality in long-lived raptor species (Zabala and Zuberogitia 2014). Most avian predators do maintain mates across years (e.g., golden eagles, common ravens) but will regularly, and quickly, replace a mate that dies or does not return to the breeding territory following migration (Watson 2010; Webb et al. 2012). Further, some individuals of these species regularly switch both mates and territories between years (Steenhof and Peterson 2009; author, unpublished data), while other species like northern harriers (*Circus cyaneus*) and Harris's hawks (*Parabuteo unicinctus*) commonly practice alternative breeding strategies like polygyny (Simmons et al. 1986) and cooperative breeding (Bednarz and Ligon 1988).

Population dynamics of many avian predators are strongly influenced by inter-annual fluctuations in prey population abundance and human presence on the landscape (Newton 2010). Several well-adapted prey species, such as leporids, prairie dogs, and prairie grouse species were abundant in rangelands until recent history (Bedrosian et al. 2019). Changes in prey, land use, and anthropogenic influences has generally led to a reduced diversity and overall population sizes of many historic raptor species and an increase in corvids and gulls in rangelands today. While many factors have influenced the decline of some species, declining prey abundance has also had significant further effects on avian predators, guild dynamics, and management actions (Newton 2010).

14.1.2 Post-fledging

The most vulnerable period for avian predator survival is after the post-fledging dependence period, or after the young disperse from their natal territory (Newton 2010; Millsap et al. 2022). Typically, mortality is the highest during this time and often a result of starvation or predation (Millsap et al. 2022). The post-fledging dependence period (after fledging but before dispersal) can range from several weeks up to > 1 year for large species like golden eagles and California condors (*Gymnogyps californianus*). Young golden eagles tracked with transmitters have been documented to have home ranges that include their natal territory for several years (Murphy et al. 2017). Habitat associations also can affect survival in various ways, depending on the species. For example, common raven post-fledging survival increased as the nest distance decreased from the nearest human settlement and subsidies (Webb et al. 2004; Bedrosian 2004), but the causes of mortality switched from natural causes to anthropogenic as ravens nested nearer to towns (author, unpublished data). Further, in desert rangelands with limited resources, raven post-fledging survival is drastically lower (38%; Webb et al. 2004) than more mesic, diverse habitats (83%; Bedrosian 2004), further indicating the importance of habitat quality on predator survival.

14.1.3 Non-breeding

Because many avian predators do not breed in their first year of life (e.g., most large-bodied raptors and ravens), the non-breeding component of the population can be large and differ in habitat use, prey use, and survival than breeding adults. Popularly referred to as “sub-adults” or “pre-breeding,” these individuals can represent a significant portion of the population within specific areas of rangelands. For example, sub-adult golden eagles occupy habitats more often associated with wintering habitat than typical breeding habitat, even in the summer months (author, unpublished data). Pre-breeding and non-breeding adult ravens also occur at anthropogenic point subsidies (e.g., landfills) to a much higher degree than breeding adults (Harju et al. 2018). The differentiation and understanding of varying habitat and space use among different age-classes of avian predators can have significant impact on management of these species across rangelands, particularly for the benefit of prey species, like greater sage-grouse (*Centrocercus urophasianus*) (Harju et al. 2018).

14.1.4 Survival

An avian predator species’ ability to adapt and evolve in response to changing habitat conditions in rangelands is a function of their reproductive rate, diet breadth, and tolerance for anthropogenic features. However, several confounding factors

also contribute to a species' persistence, including sensitivity to chemicals or toxic elements and plasticity in habitat selection. California condors are at one extreme of that spectrum, with little ability to adapt quickly to changing landscapes and a low tolerance of toxic elements in their environment (Finkelstein et al. 2020). Historically, carcasses of American bison (*Bison bison*) and other big-game sustained their populations but as bison and large carnivores were eventually replaced with livestock across the range, the abundance of carcasses available to scavengers dwindled. The species shifted to other available carrion, like hunter-harvested big game and euthanized livestock. The decreased abundance of food, coupled with their increased mortality from ingesting lead ammunition fragments in gut piles and non-steroidal anti-inflammatory drugs in deceased livestock, further exacerbated their decline (Finkelstein et al. 2012). At the other end of the spectrum are species like common ravens, great-horned owls, and red-tailed hawks. Unlike many other predators, these species' evolutionary history has led to a greater tolerance of human activities, wide diet breadth, and the ability to nest in a wide range of habitats and climates; all of which has led to their expansion in many human-altered habitats, including rangelands (Boarman and Heinrich 2020).

Post-fledging, most avian predators have high survival with species like golden eagles nearing 90% annual survival rates for adults and 70% for first-year golden eagles in western rangelands (Millsap et al. 2022). Cause specific mortality for young avian predators is mostly due to natural causes (e.g., starvation and predation) but eventually switch to primarily human-caused mortality in older-age classes (see Sect. 14.4).

14.1.5 Seasonal Movements and Dispersal

The diverse migratory behaviors of avian predators have led to large seasonal shifts in abundance and distribution across rangelands. Some species exhibit complete migration, like Swainson's hawks (*Buteo swainsoni*), which occupy rangelands only during the breeding season, then migrate to South America during the non-breeding season. Similarly, rough-legged hawks (*Buteo lagopus*) breed in the arctic tundra and migrate south to winter in rangelands. Other species that make nomadic or irruptive migratory movements, like short-eared owls (*Asio flammeus*), can have different breeding territories each year, sometimes hundreds of kilometers apart (Shaffer et al. 2021). Corvids typically do not exhibit migratory movements in the classical sense but can drastically increase their home ranges during the non-breeding season and occur more often in areas of anthropogenic subsidies compared to the breeding season (Harju et al. 2018). Species of gulls that occupy rangelands, like California Gulls (*Larus californicus*) and Ring-billed Gulls (*Larus delawarensis*) typically migrate during the winter to western coasts, but some small populations overwinter along the Snake River corridor and near Great Salt Lake (Pollet et al. 2020; Winkler 2020). Snowy owls (*Bubo scandiacus*), which breed in the arctic, make irruptive migrations to the coterminous US in years of high prey abundance in northern rangelands

(Robillard et al. 2016). Other species employ a mixture of these strategies, like ferruginous hawks (*Buteo regalis*), which maintain disparate breeding and wintering ranges across years (both typically in rangelands) but make nomadic (typically northern) movements after breeding during late summer, followed by a typical migration to more southern latitudes (Watson et al. 2018; Watson and Keren 2019). Finally, some species exhibit diverse migratory patterns that vary across their range and life stages. For example, golden eagles can be (1) year-round residents in much of the coterminous US (Crandall et al. 2015), (2) complete, long-distance migrants from the arctic tundra and grasslands of Canada (Bedrosian et al. 2019), (3) migrate north from the arid southwest (Murphy et al. 2018), or (4) have very large but no regular seasonal ranges across multiple states (Poessel et al. 2022). All these sub-groups generally converge in the grassland and sage-steppe rangelands of the U.S. during the winter months. The diversity of migratory patterns within and among species results in dynamic variation in the assemblage of rangeland avian predators in space and time.

14.1.6 Population Dynamics

Species composition of avian predator communities in rangelands has shifted in response to alterations in habitat composition, prey abundance, and anthropogenic use (Donazar et al. 2016). Changes in habitat are largely driven by anthropogenic causes, ranging from increased fragmentation, conversion, invasive plants, fire, and combinations of these factors. Predators that have evolved in rangelands typically occupy large seasonal ranges and have reproductive strategies to accommodate fluctuating prey populations and dispersed resources (Johnson et al. 2022). This reliance on large home ranges in rangelands can lead to negative population consequences as fragmentation of these landscapes increase.

Some human-tolerant species have significantly increased in rangeland habitats due, in part, to increased anthropogenic use and alteration of rangelands (Coates et al. 2016; Boarman and Heinrich 2020). While several species of raptors and gulls are included in this group, corvids are the most significant example of this across the West. Historically occurring in low densities across the deserts, sage-steppe, and grasslands, corvids have had unparalleled expansion into rangelands due to several compounding factors (Bui et al. 2010). First, their plasticity in both habitat selection and foraging strategies has allowed ravens to occupy nearly every type of habitat in the West. Second, declines in other raptor species can decrease inter-specific competition that may have otherwise excluded corvids. Finally, anthropogenic food, water, and nesting subsidies in rangelands are more readily used by corvids and gulls due to their human tolerance (Harju et al. 2018; Winkler 2020) and these subsidies create nesting territories where they historically would not have occurred (e.g., ravens do not nest on the ground). However, some species considered obligates of native rangelands may also benefit from some degree of habitat heterogeneity resulting

from agriculture and human infrastructure, such as ferruginous hawks nesting on anthropogenic structures (Wallace et al. 2016b). These population shifts comes with significant management challenges from declining raptor populations to native prey species management.

The complexities of intra- and inter-specific habitat use, seasonality, competition, and human tolerance are among the many factors that make avian predator management difficult in changing rangelands across North America. Avian predator habitat selection typically occurs at larger scales in rangelands than more heterogeneous or productive landscapes, which can complicate management actions. Management efforts must address multiple ecosystem-level processes, spatial scales, trophic cascades, and multiple species to be effective.

14.2 Current Species and Population Status

Numerous avian predator species occupy North American rangelands from the northern arctic tundra to the southern deserts. The large and diverse types of rangelands host both specialized and generalist avian predators. While very few raptor species rely solely on rangelands for year-round habitat needs, rangelands provide important seasonal habitat with a wide and vast array of avian predators. Rangelands occur in most avian predator home-ranges across the West and these habitats are essential for large portions of many populations.

Herein, the focus is on avian predators of rangeland habitats south of the boreal forests in North America and exclude forest-obligate species (Table 14.1). However, forested habitats may be used for livestock grazing and forest-obligate raptors may also be affected by rangeland management practices that are adjacent to forests or woodlands. Several distinct groups of avian predators occur within western rangelands, including raptors (i.e., eagles, hawks, owls), corvids (i.e., ravens, crows, magpies), vultures, and gulls. Each group and species have unique habitat and management needs and may occupy different rangelands in different seasons. Most avian predators occupy various rangeland types year-round and populations of predators typically increase in winter as northern migrants flood into the habitats occupied by year-round residents in the coterminous US. The best example of this phenomenon is golden eagles (see above), which may pose additional management complications for both predator and prey species.

14.2.1 *Golden Eagles*

One of the largest raptors in North America, the golden eagle regularly occurs in and largely relies on western rangelands. Golden eagles are year-round residents in much of the western North America and their breeding range extends from Alaska and the Canadian arctic to Mexico (Katzner et al. 2020a, b). Golden eagle populations are

Table 14.1 List of avian predator species occupying rangeland in western North America, typical rangeland habitat association, and population status (IUCN; www.iucn.org)

General avian predator class				
Order	<i>Genus Species</i>	Season	Rangeland	Status
Common name			Type	
Diurnal Raptors				
<i>Accipitridae</i>				
Golden Eagle	<i>Aquila Chrysaetos</i>	Year-round	Shrublands, Grasslands	Stable/ Declining
Bald Eagle	<i>Haliaeetus leucocephalus</i>	Year-round	Grasslands	Increasing
Ferruginous Hawk	<i>Buteo regalis</i>	Breeding	All	Stable/ Declining
Swainson's Hawk	<i>Buteo swainsoni</i>	Breeding	Grasslands	Unknown
Rough-legged Hawk	<i>Buteo lagopus</i>	Winter	Grasslands, Shrublands	Unknown
Red-tailed Hawk	<i>Buteo jamacensis</i>	Year-round	All	Stable
Harris's Hawk	<i>Parabuteo unicinctus</i>	Year-round	Desert, shrublands	Stable/ Increasing
Northern Harrier	<i>Circus hudsonius</i>	Year-round	Grasslands, shrublands	Stable
Mississippi Kite	<i>Ictinia mississippiensis</i>	Breeding	Grasslands	Stable/ Increasing
White-tailed Kite	<i>Elanus leucurus</i>	Breeding	Grasslands	Declining
<i>Falconidae</i>				
Prairie Falcon	<i>Falco mexicanus</i>	Year-round	All	Unknown
Aplomado Falcon	<i>Falco femoralis</i>	Year-round	Desert	Critically endangered
American Kestrel	<i>Falco sparverius</i>	Year-round	All	Declining
Merlin	<i>Falco columbarius</i>	Year-round	Grasslands	Unknown
Peregrine Falcon	<i>Falco peregrinus</i>	Year-round	Shrublands	Increasing
Gyr Falcon	<i>Falco rusticolus</i>	Winter	Grasslands	Stable/ Increasing
Crested Caracara	<i>Caracara cheriway</i>	Year-round		Unknown
Nocturnal Raptors				
<i>Strigidae</i>				
Burrowing Owl	<i>Athene cunicularia</i>	Breeding	Grasslands	Declining
Short-eared Owl	<i>Asio flammeus</i>	Year-round	Shrublands, grasslands	Unknown
Elf Owl	<i>Micrathene whitneyi</i>	Year-round	Desert	Unknown

(continued)

Table 14.1 (continued)

General avian predator class				
Order	<i>Genus Species</i>	Season	Rangeland	Status
Common name			Type	
Ferruginous Pygmy Owl	<i>Glaucidium brasilianum</i>	Year-round	Desert	Declining
Long-eared Owl	<i>Asio otus</i>	Year-round	Shrublands, grasslands	Unknown
Great-horned Owl	<i>Bubo virginianus</i>	Year-round	All	Stable
Snowy Owl	<i>Bubo scandiacus</i>	Winter	Grasslands	Declining
Tytonidae				
Barn Owl	<i>Tyto alba</i>	Year-round	Shrublands, grasslands	Unknown
Corvids				
<i>Corvidae</i>				
Common Raven	<i>Corvus corax</i>	Year-round	All	Increasing
Chihuahuan Raven	<i>Corvus cryptoleucus</i>	Year-round	Desert	Stable
American Crow	<i>Corvus brachyrhynchos</i>	Year-round	All	Increasing
Black-Billed Magpie	<i>Pica hudsonia</i>	Year-round	Shrublands, grasslands	Stable
Vultures				
<i>Cathartidae</i>				
Turkey Vulture	<i>Cathartes aura</i>	Breeding	All	Increasing
Black Vulture	<i>Coragyps atratus</i>	Year-round	All	Increasing
California Condor	<i>Gymnogyps californianus</i>	Year-round	Shrublands, desert	Critically endangered
Gulls				
<i>Laridae</i>				
Franklin's Gull	<i>Leucophaeus pipixcan</i>	Year-round		Stable
Ring-billed Gull	<i>Larus delawarensis</i>	Year-round		Stable
California Gull	<i>Larus californicus</i>	Year-round		Stable

believed to be stable in North America in recent decades (Millsap et al. 2013). Despite apparent stability of golden eagle populations in the western US from 1968 to 2014 (Millsap et al. 2013), population projections suggest current rates of human-caused mortality are sufficient to cause a decline in the future (Millsap et al. 2022). Golden eagles use a wide range of open habitats where they prey primarily on mammals and nest on cliffs and/or trees. This contrasts with significantly increasing populations of bald eagles (*Haliaeetus leucocephalus*), whose habitat is more strongly associated

with lakes and rivers that provide foraging habitat and nesting trees. The long-lives and delayed reproduction of golden eagles, coupled with diverse migratory strategies, results in multiple population segments co-occurring and potentially competing in western rangelands. These include resident breeders that hold territories year-round, sub-adult residents that may occupy larger yearly ranges or wander, and a vast number of migrants that breed across Canada and Alaska and migrate long distances into the conterminous U.S. every winter.

Eagles have been targets of widespread human persecution across rangelands (Bedrosian et al. 2019) even though they receive a special degree of legal protection under the Bald and Golden Eagle Protection Act (BGEPA; 16 U.S.C. 668-668c). The largest source of mortality for golden eagles is natural starvation or disease for first-year eagles, anthropogenic poisoning for sub-adults, and shooting for adults (Millsap et al. 2022). This underscores the historic and continued, contemporary persecution of eagles. In recent years, both eagle species have been the subject of concern because of their vulnerability to mortality from collisions with wind turbines, with golden eagles especially at risk (Pagel et al. 2013). Eagles are also affected by other common risks to large raptors, including electrocution, vehicle collisions while foraging on road-kill, and lead poisoning. Golden eagles are particularly vulnerable to electrocution because of their broad wingspan and frequent use of power poles for perching in open habitats (Mojica et al. 2017).

Golden eagles are powerful and regular predators in most rangelands, preying mainly on rabbits, hares, ground squirrels, and prairie dogs but also taking larger prey such as antelope, deer, sheep, and young livestock (Bedrosian et al. 2017). However, they are also facultative scavengers, which exposes them to risks like lead poisoning from eating lead fragments in hunter-harvested game and gut piles (Bedrosian et al. 2012; Langner et al. 2016; Slabe et al. 2022) and vehicle collision when feeding on road-killed ungulates (Slater et al. 2022). Golden eagles may have increased mortality risk during winter when scavenging increases and secondary factors like sub-lethal lead intoxication occurs. Scavenging can also result in eagles congregating at ranches during lambing and calving to feed on afterbirth or stillborn livestock. This behavior can be associated with opportunistic predation on young livestock, but more often to the perception of livestock predation risk (Bedrosian et al. 2019).

Golden eagles rely on native rangelands for nesting and foraging habitat. Reproductive output is tied to inter-annual fluctuations in prey abundance, while occupancy of territories is consistent across long time periods (Kochert and Steenhof 2012). Fluctuations in productivity of golden eagles can be dramatic in areas where prey populations fluctuate cyclically or from epizootics (C. Preston, personal communication). Sage-steppe and grassland habitats host most breeding eagles in the coterminous US, which likely a function of where their main prey occur (Nielson et al. 2016). The proportion of golden eagles nesting in trees (both deciduous and coniferous) can be near 50% (Crandall et al. 2016) in heterogenous habitats and closer to 100% in the Great Plains, where loss of older-aged cottonwoods that provide some of the only nesting substrate is a conservation concern for golden eagles (Bedrosian et al. 2019). Cliff nests are often reused and as many as 39 years has been recorded

between uses (Kochert and Steenhof 2012). Some nests are used regularly and for many generations. One golden nest on a basalt cliff in Montana was estimated to be more than seven meters tall and measured at > 500 years-old based on carbon dating of a stick from within the base of the nest (Ellis et al. 2009). It is suggested that nests be protected for at least 10 years after their last confirmed use (Kochert and Steenhof 2012). The longevity of nest sites highlights the importance of conserving raptor nesting sites and territories for generations.

14.2.2 *Buteo Hawks*

As large-bodied hawks, most *Buteo* species world-wide use a perch-and-pounce hunting strategy. However, perches have historically been limited across rangelands and the wing-shape, flight dynamics, and foraging strategy of *Buteos* that have evolved on rangelands is notable. The *Buteos* most associated with rangelands in the U.S. either employ a more aerial-based or ground-based hunting strategy than congeners in forested and mixed habitat types. *Buteo* species co-occurring in rangeland systems partition habitat based on both nesting substrates (Restani 1991; Kennedy et al. 2014) and diet (MacLaren et al. 1988).

The most rangeland-specialist *Buteo* is arguably the ferruginous hawk, which is the largest hawk species in North America by mass and wingspan (Ng et al. 2020). This species has the greatest conservation need of *Buteos* regularly occurring in rangelands but other species, like Swainson's and Harris's hawks, may also have local conservation concerns. The broad wingspan of this grassland, shrub-steppe, and desert raptor allows for efficient long-term soaring to augment its perch and pounce hunting strategy. The large body size of ferruginous hawks is likely a reflection of the larger size of its main prey: jackrabbits, prairie dogs, and ground squirrels (Ng et al. 2020). Historically associated with open habitats in western rangelands, ferruginous hawks have adapted to nesting on the ground where trees, cliffs, or other elevated substrates are absent.

Like most raptors, ferruginous hawk populations are assumed to have significantly declined from historical abundance. While listed as a federally threatened species in Canada between 1980 and 1995 and again since 2010 due to declining numbers, most breeding populations are generally considered stable in the US with some evidence of recent declines in grassland habitats (Sauer et al. 2017). Like other raptors of grasslands and shrub-steppe, productivity of ferruginous hawks can fluctuate with prey populations and some regional declines have been linked to declines in prey species, like jackrabbits (Smith et al. 1981). There is some evidence to suggest this species is particularly sensitive to human disturbance (White and Thurow 1985; Keeley and Bechard 2011). In experimental trials in Canada, disturbance of nesting hawks was greater from foot traffic than vehicles and in more remote areas (Nordell et al. 2017). Loss and fragmentation of native habitats (Coates et al. 2014) by tillage agriculture (Schmutz 1987) has negatively affected breeding success of ferruginous hawks, possibly because of the sensitivity of this species to disturbance at nest sites.

Ferruginous hawks may, however, benefit from other anthropogenic modifications of their habitat, including some types of roads (Gilmer and Stewart 1983; MacLaren et al. 1988), prey in edge habitats (Zelenak and Rotella 1997; Keough and Conover 2012), and anthropogenic structures for perching and nesting (Steenhof et al. 1993; Keough and Conover 2012), including nest platforms installed for habitat enhancement and mitigation (Tigner et al. 1996; Wallace et al. 2016a, b). Previous studies on effects of roads and oil and gas well pads on ferruginous hawks are equivocal: some document positive relationships of productivity and roads (Zelenak and Rotella 1997), occupancy and roads (Neal et al. 2010; Wallace et al. 2016a; Squires et al. 2020), and occupancy and well pads (Keough and Conover 2012), whereas others report negative relationships of occupancy (Wiggins et al. 2017) and productivity with well pads (Harmata 1991; Keough 2006), and no apparent response of occupancy (Wallace et al. 2016a) or breeding success (Van Horn 1993; Wallace et al. 2016b) to well pads.

Habitat selection and breeding performance of ferruginous hawks are also influenced by natural factors, including vegetative cover (Wallace et al. 2016a; Squires et al. 2020), prey abundance (Smith et al. 1981; Schmutz et al. 2008), congeneric competition (Restani 1991), spring weather (Gilmer and Stewart 1983; Wallace et al. 2016b), and availability of nesting substrates (Kennedy et al. 2014). Somewhat unique to ferruginous hawks, individuals engage in wide-ranging nomadism post-breeding before their fall migration (Watson and Keren 2019; author unpublished data). The late-summer nomadic movements can be > 800 km in the opposite direction of their winter range (Watson et al. 2018). All seasonal habitats are typically associated with prey habitat (i.e., prairie dogs) but may be more tied to agriculture during the winter months compared to breeding habitats.

14.2.3 *Burrowing Owls*

Owls are largely nocturnal predators that occur in diverse habitats, where they take a wide variety of prey from insects to medium-sized mammals. Species in North American rangelands vary from rare habitat specialists, like the burrowing owl, to widespread generalists, like the great-horned owl, and their distributions span the continent from the Arctic tundra breeding grounds of the snowy owl to the preferred nesting habitat of the elf owl (*Micrathene whitneyi*) in cacti of the Sonoran Desert.

The western subspecies of the burrowing owl can be considered one of the few raptor species that are reliant on rangelands, with breeding habitat in open grasslands, shrub steppe, and deserts (Shaffer et al. 2022; Poulin et al. 2020). This semi-fossorial owl is dependent on burrowing mammals, such as prairie dogs and ground squirrels, to excavate tunnels that the owl uses as nest sites. Burrowing owls prefer short-grass prairies or areas where vegetation has been grazed to short heights, and most often select burrows in active prairie dog colonies. Colonies abandoned for even one year can be unsuitable for owls (Shaffer et al. 2022). This species generally avoids agricultural areas in native rangelands but does occur in both agricultural and

urban habitats in some portions of its range. For example, in Canada, burrowing owls are almost exclusively found in native grasslands (Poulin et al. 2005), while owls in southern Idaho have benefited from being near irrigated agriculture due to increased prey densities there (King and Belthoff 2001). Native pastures may be used more readily for nesting than re-seeded, historical croplands (e.g., Conservation Reserve Program) (Shaffer et al. 2022). Burrowing owls are listed as endangered in Canada, threatened in Mexico and Colorado, and a species of concern for most other states. The species faces primary threats such as native habitat conversion and loss of prairie dog and ground squirrel colonies from control measures and plague. As a migrant species, they also have added habitat needs and management challenges across seasons. Because invertebrates comprise the most frequent prey for burrowing owls, insecticides can significantly reduce reproductive success or lead to direct and indirect mortality (James and Fox 1987). Similarly, pesticides applied to control mammals may also affect survival and reproduction of owls (James et al. 1990).

14.2.4 *Corvids*

The well-documented intelligence of ravens, crows, and magpies make them adaptable, effective predators and opportunists in North American rangelands. Currently, corvids present some of the greatest conservation challenges to other sensitive species across rangelands since they, themselves, are native species. Corvids are often considered “invasive species” by the public and some managers since their populations are rapidly expanding across many rangeland habitats, primarily because of human alterations of the landscape (Boarman and Heinrich 2020). Ravens typically nest on trees and cliffs but take advantage of many other available nesting structures. In many areas with energy development, ravens have adapted to nesting on oil and gas infrastructure or other anthropogenic substrates, including abandoned buildings, windmills, power lines, billboards, and virtually any elevated structure in rangeland habitats where food and water subsidies exist. This species now presents conservation challenges by predating various native wildlife species of concern, including greater sage-grouse and desert tortoise (*Gopherus agassizii*) (Boarman and Heinrich 2020). Similarly, the distribution of the American crow (*Corvus brachyrhynchos*) has expanded since European settlement as clearing of forests, expansion of agriculture, planting of trees in the Great Plains, and urban sprawl have created more open, human-altered habitats. Crows are efficient avian nest predators and are also considered agricultural pests in some areas, where flocks damage crops, like grains and tree fruits (Verbeek and Caffrey 2020).

14.3 Population Monitoring

Because avian predators typically occur in low densities and have large home ranges, monitoring population trends and status can be difficult at large scales. While citizen-science counts, such as the Breeding Bird Survey, Christmas Bird Count, and Mid-winter Bald Eagle Count, can inform long-term trends for many species, data for rarely encountered species, like most raptors, are difficult to interpret and do not capture variation away from roadways. Raptor space use does not conform to typical bird conservation administrative boundaries that many broad monitoring efforts have been based on, e.g., Bird Conservation Regions, flyways, Migratory Bird Joint Ventures, Landscape Conservation Cooperatives (Brown et al. 2017). Standardized data for nesting raptors and information sharing among agencies, industry, and non-governmental organizations has been lacking but would significantly help management actions across rangelands. There have been several publications dedicated to terminology used in nest monitoring (Steenhof 2017), some states have raptor working groups (UT, WY, CA) and Wyoming recently developed state-wide monitoring protocols and datasheets to address this concern. More widespread coordination of population monitoring efforts across the West would be beneficial to many agencies and conservation actions.

Recently, the USFWS developed a range-wide monitoring program to assess the status of Golden Eagles in the western U.S. (Millsap et al. 2013; Nielson et al. 2014; Nielson et al. 2016). This significant effort uses a combination of distance sampling (Thomas et al. 2010) and mark-recapture methods (Borchers et al. 2006) to estimate the population size detection probability for golden eagles observed during standardized aerial transect surveys. The method can be used to infer population trends at large scales (e.g., bird conservation regions). While this monitoring program is the first to undertake such a large-scale effort to estimate population trends for raptors at the population-level, the data are likely insufficient to detect trends at smaller spatial scales (e.g., State of Wyoming) without additional transects added. The difference in nesting timing between avian predator species in rangelands also contributes to inefficiencies in monitoring efforts. For example, golden eagles begin nesting in February–March while ferruginous hawks are not reliably back from their wintering grounds until May. Attempting to survey for multiple species simultaneously may miss early eagle nest failures or late arriving raptors without careful coordination.

14.4 Habitat Associations

14.4.1 *Historical Habitat Use*

Species composition was likely very different prior to European settlement of the western rangelands for several reasons. Most open-habitat raptors have evolved in varying landscapes of prairie and shrub-steppe ecosystems. While each ecological

sub-region has varying conditions, several historical habitat features, such as fire regimes and mammal assemblages, likely influenced the composition and abundance of avian predator species. Most raptor species prefer foraging in shorter grasslands for easier visual access to prey, which were more abundant in fire-rich and/or ungulate-grazed prairie habitats. Native American and First Nations peoples may have helped maintain fire within some grassland systems to hunt bison *en masse* (Roos et al. 2018), both of which would have benefited avian predators and scavengers. The ecology of the grasslands of the plains and prairie states was largely different than current conditions due to the historical presence and abundance of ungulates and large carnivores. It is suspected that species like common ravens and California condors were more abundant across the grasslands in the nineteenth century as a result (Boarman and Heinrich 2020). Similarly, the historical widespread abundance and distribution of prey, such as large prairie dog and ground squirrel colonies and prairie grouse populations likely supported large raptor populations.

Another important factor influencing avian predator distribution and abundance is the large negative effect of direct human persecution. Virtually all avian predators were actively persecuted throughout the late nineteenth and the majority of the twentieth century. Government bounties existed for most raptors and shooting, trapping, and poisoning of predators was encouraged and practiced for generations (Madden et al. 2019). Secondary poisoning and trapping of raptors from mammalian predator control was also widespread across rangelands.

Finally, habitat conversion from native grasslands and shrub-steppe to agriculture was a significant driver of species abundance and composition that remains a management challenge today. Much of middle North America was historically prairie habitat that likely supported large populations of nesting raptors that currently are considered rangeland species. As native habitats were lost to urbanization or converted to agriculture, the species relying on these habitats either adapted to new habitat types or experienced range contraction and population declines.

14.4.2 Contemporary Habitat Use

As with most wildlife species, the ability to quickly alter behaviors with changing habitats and perturbations has been a major driver of species' abundance and distribution in rangelands. While some habitats and resources have remained intact, like large swaths of sage-steppe in Wyoming, all ecosystems have been altered in one way or another. Bison and other native large ungulates have largely been replaced with livestock and large mammalian predators have been removed or significantly reduced in abundance in almost all systems. Many habitats have been converted from native grasslands and shrub-steppe to agriculture or development. This conversion both reduces nesting habitat, particularly for ground-nesting raptors, and can reduce and alter prey populations. The remaining grasslands and shrublands provide

extant rangelands but are threatened by invasive plant species like cheatgrass (*Bromus tectorum*), which has significantly altered the severity and frequency of fire and is subsequently affecting raptor productivity (Slater et al. 2013).

Undoubtedly, the avian predator guild species composition has been drastically shifting over the last century and has been a continual management challenge for conservation-reliant prey species like greater sage-grouse and desert tortoise. Specialized species historically associated with native habitats, but now associated with remaining rangelands, are generally struggling to maintain population viability and more human-tolerant species are replacing those specialized species. Similarly, specialized prey populations (e.g., sage-grouse) have been declining for similar reasons but are further exacerbated by this shift in the avian predator community. Without exception, all avian predator species currently in North America's rangelands have been historically present, albeit in different densities over time. Increased human presence and alteration of the landscape has negatively influenced the occurrence of sensitive species, fragmented habitat that influenced prey populations, directly reduced both prey and predator populations, increased anthropogenic subsidies of water, food, and nesting structures. As each species reacts differently to these factors, the guild dynamics of avian predators continues to shift towards those species tolerant of and subsidized by human activities.

14.5 Rangeland Management

The management of each species is unique, and recommendations required for successful avian predator ecosystem management include the species-specific management, in addition to management of prey populations and anthropogenic use of rangelands. Management of grazing, fire, invasive species, habitat patch size, and many other factors can be unique for many species, but generalizations can be applied to two basic sub-groups of avian predators in rangelands: human-intolerant and human-subsidized species. Across the West, the general trend over time has been increasingly challenging for conserving the former while reducing the latter.

14.5.1 Livestock Grazing

The largest ecological connection between livestock grazing and avian predator species abundance and richness is the interaction of grazing with prey species. While little work has been dedicated directly to the link between grazing and raptors, Johnson and Horn (2008) found that raptor abundance decreases in grazed pastures of mesic coastal grasslands in California because of lower rodent density. In Mediterranean grasslands, an experiment that increased European kestrel (*Falco tinnunculus*) populations in grazed pastures did not additively decrease small mammal abundance or richness, meaning grazing was the driving factor in small mammal declines, not

avian predators. World-wide, high- and medium-intensity grazing has been shown to decrease small mammal abundance and diversity by reducing available forage and increasing soil compaction (e.g., Eccard et al. 2000; Saetnan and Skarpe 2006; Torre et al. 2007; Cao et al. 2016). In any system with decreased small mammals, the abundance of raptors dependent on those prey will follow similar trends.

Often, confounding factors of annual precipitation and wildfire have been interwoven with studies assessing grazing effects on small mammal communities (Yarnell et al. 2007; Bock et al. 2011), with low-intensity grazing and fires appearing to have some benefit to small mammal diversity in some areas. However, it appears that grazing has a larger impact on small mammal communities than both wildfire and meadow wetness (Horncastle et al. 2019).

The simple presence of livestock on rangelands can also be directly correlated with abundance of human-subsidized predators, like common ravens. The odds of raven occurrence can increase as much as 45% when free-range livestock are present compared to similar habitats without cattle (Coates et al. 2016). This association is not clear but may be linked to water provided to cattle or increased insect availability for foraging around and under cattle fecal piles.

14.5.2 *Predator Control*

Beyond the ecological connection, humans and avian predators have a long, adversarial history on rangelands. Because raptors can, and do, prey on livestock, gamebirds, and sensitive wildlife species, there have been illegal and legal control actions taken against avian predators. In a survey of 274 ranchers in Wyoming, Scasta et al. (2017) found that avian predators accounted for 19% of all livestock losses in the year prior to the survey. However, this survey also included turkey vultures (*Cathartes aura*) as an avian predator. While turkey vultures are technically considered raptors (McClure et al. 2019), they are an obligate scavenger incapable of killing livestock (Kirk and Mossman 2020) and its inclusion in the study highlights the inaccurate assumption that avian scavengers (e.g., eagles, ravens, magpies) feeding on a carcass or afterbirth preyed on that animal. The inability to distinguish scavenging from predation can lead to both artificially inflated estimates of avian predation on livestock and to continued negative perceptions of avian predators (Scasta et al. 2017).

Eagles are federally protected species by both the Migratory Bird Treaty Act (MBTA) and the BGEPA. Corvids and other raptors are all protected by the MBTA, but American crows are also considered a game and/or varmint species in many states and can be legally harvested during particular seasons, often times without a hunting license or bag limits (e.g., Wyoming). Common ravens are not a game species in any state and misidentification from hunters between crows and ravens can be a problem in areas where the species ranges overlap. However, regardless of their legal protections, many avian predators are illegally poisoned, shot, and trapped. Additionally,

USDA Wildlife Services and local animal control boards have permissions to control tens-of-thousands corvids across the West suspected of impacting both livestock and game species, such as greater sage-grouse.

Golden eagles can predate young calves, lambs, ewes, and rams and are greatest threats in open country lambing operations and predation events typically involve young lambs or goats (Phillips and Blom 1988; Matchett and O’Gara 1991; Avery and Cummings 2004). In just one year of low leporid (i.e., rabbit and hare) abundance in South Dakota, golden eagles were verified to depredate at least 142 lambs from seven ranches (Waite and Phillips 1994). Legal action for ranchers is typically very onerous and time consuming, which can involve hiring local, state, or federal control officers for species other than eagles, and all means of avian predator abatement have shown very little effectiveness (Scasta et al. 2017). Several historical attempts to relocate golden eagles to reduce lamb predation have occurred, but have not been successful, with most adults (12 of 14) returning within 11–316 days, even after being moved > 400 km (Miner 1975; Phillips and Blom 1988; O’Gara and Rightmire 1987; Phillips et al. 1991). One study relocated 432 golden eagles from ranchlands near Butte, Montana, but the effort resulted in little to no effect on lamb depredation rates from 1975 to 1983 (Avery and Cummings 2004). This lack of ability for producers to deal with predation from raptors can lead to animosity and/or illegal killing of these avian predators. Increased research and experimentation to determine how to control depredation more efficiently will help alleviate this issue.

14.5.3 Fire

Given the diverse habitat associations of avian predators across rangelands, fire can have varied effects for different species. In general, both prescribed and wild fire can have negative effects on sensitive species of nesting raptors (e.g., Marzluff et al. 1997; Kochert et al. 1999). Fires during the nesting season can destroy cover and active ground nests for species like northern harriers, short-eared owls, and ferruginous hawks (Johnson et al. 2019). Large wildfires can also destroy the few nesting trees that occur across rangelands thereby eliminating nesting territories if no other nesting structure is present.

Fires not only affect nesting structures, but also prey populations that can indirectly affect raptors. Because fires in scrublands significantly change the habitat type, fires in those ecotypes may affect raptors to a greater degree than in prairies and grasslands which are more adapted to fires. For example, golden eagles in shrubland habitats had significantly reduced productivity post-fire (Kochert et al. 1999). The increase in annual invasive grasses (i.e., cheatgrass) further exacerbated this issue by both reducing prey habitat and increasing future fire risk. In a 44-year study of golden eagle productivity and diet relative to wildfires, Heath et al. (2021) found that eagles were able to shift their diets from typical, preferred scrub prey species (i.e., lagomorphs) to a more diverse diet, but at the expense of productivity due to novel diseases which may result in negative population-level effects.

14.5.4 Water Subsidies

Providing artificial water sources in rangelands for livestock also can impact avian predators, both in positive and negative ways. Anthropogenic sources of water can be very beneficial in many arid and semi-arid landscapes. However, most raptor species obtain their water through their food and do not often directly drink water. Corvids and gulls, however, can significantly benefit from these water sources in an otherwise inhospitable environment (Kristin and Boarman 2007). This type of anthropogenic subsidy may affect abundance of these species in habitats they otherwise would not occur in. Raptors and other wildlife have been observed drowning in stock tanks when escape ladders are not provided. Raptors likely use these stock tanks for bathing and cooling but can have a difficult time escaping after becoming wet. A variety of simple ladders and ramps are readily available and increasingly used to mitigate this source of mortality (Rocky Mountain Bird Observatory 2006).

14.6 Impacts of Disease

Raptors have been found to be particularly susceptible to strains of avian influenza (Shearn-Bochsler et al. 2019) and West Nile virus (Nemeth et al. 2006) but transmission in rangelands is likely limited. Avian influenza can be transmitted from exposure between poultry farms and waterfowl. West Nile virus is likely more of a concern for both raptors and corvids in rangelands, with transmission occurring from foraging on infected prey and from mosquito transmission while nesting. Walker and Naugle (2011) provide an overview of West Nile virus ecology in sagebrush habitats and Bedrosian et al. (2019) and Wallace et al. (2019) provide reviews of transmission incidence in golden eagles on rangelands that can likely be applied to other raptor species. West Nile virus occurrence has also been documented in ferruginous hawks (Datta et al. 2015), burrowing owls and American kestrels (Dusek et al. 2010), and likely occurs in most raptor species. The larval habitats of the main mosquito vector for West Nile virus (*Culex tarsalis*) are small areas of standing water (< 4 ha) with high organic matter (Beehler and Mulla 1995). Most mosquito breeding areas in rangelands are created by human activities, including livestock watering ponds, water-storage areas, and discharge watering ponds in coalbed methane extraction regions (Denke and Spackman 1990). Irrigated agricultural sources of larval ponds produce significantly less mosquitos than coalbed methane ponds and outlets, and for a shorter duration (Doherty 2007). Further, Zou et al. (2006) mapped potential mosquito breeding areas through remote sensing in the Powder River Basin and found a 75% increase in area of potential larval habitats from 1999 to 2004, particularly in coalbed methane extraction areas. Drought may exacerbate outbreaks by concentrating mosquitos in restricted water sources from anthropogenic sources. Prevalence of outbreaks is predicted to increase by 2050 in the West (Harrigan et al. 2014) with substantial increases because of climate change (Schrag et al. 2011).

14.7 Ecosystem Threats

Anthropogenic changes to the North American rangelands can have drastically varying effects on avian predator species. Habitat fragmentation and/or loss through conversion to agriculture or development can lead to declines in species typically associated with native habitats, such as ferruginous hawks and golden eagles, while simultaneously increasing more human-tolerant and dependent species like common ravens, California gulls, great horned owls, and red-tailed hawks. The interconnected nature of these shifts is difficult to tease apart into direct, cause-effect relationships (see above). As rangelands and their predator composition change, the ecosystem-level changes further threaten sensitive species reliant on native rangeland.

14.7.1 *Human-Persecution*

Avian predators have a long-standing, typically negative, association with humans across all rangelands. Raptors have had long-standing direct conflict with people because they are predators of livestock (economic loss), wildlife people hunt (direct competition), and sensitive species (management conflicts). Corvids have a long-standing negative association within many European cultures dating back to medieval times when ravens and crows fed on human corpses after battles and during the bubonic plague (Król and Hernik 2020).

Indirectly, many raptors are affected by persecution of their prey too, which are often suppressed by humans due to competition for limited forage with livestock. Further, a minority of recreational shooters of small game and varmints illegally shoot non-game animals, often avian predators, in rangelands (Katzner et al. 2020a, b). Because of the link between avian predators and sensitive species that have cascading management implications and restrictions to private lands and industry, this increases pressure to reduce avian predator populations. Increased management and raptor-specific restrictions on extractive industries like mining, oil, and gas development has further created a negative sentiment for raptors across rangelands due to concerns over economic losses. All these reasons contribute to the ongoing direct human persecution through illegal shooting, poisoning, and trapping of avian predators, even with additional federal protections in place.

Raptors are most vulnerable to persecution while incubating or activities otherwise associated with nesting behavior. Most raptors nesting in rangelands have large, conspicuous nests because there are few places to hide a large stick nest. This conspicuousness and increased human persecution have likely led to behavior responses that avoid humans. As such, some raptors exhibit a large degree of sensitivity and increase flushing rates from their nests when associated with anthropogenic

disturbances (Keeley and Bechard 2011). As human occurrence increases in rangelands, these sensitivities become exacerbated and may lead to population declines for human-intolerant species.

14.7.2 Habitat Conversion and Invasive Species

Conversion of native grassland and shrubland habitats to cultivated crops is a large driving factor in predator species composition in rangelands. Habitat conversion to agriculture tends to reduce foraging habitat for most raptors by reducing native prey habitat (e.g., scurids and lagomorphs). The Great Plains have already experienced significant habitat loss since European settlement and is expected to increase in the next 100 years due to climate change making grasslands more suitable for agriculture and increasing demand for biofuels (Sleeter et al. 2012; Sohl et al. 2012). Further, livestock grazing, which can reduce prey populations (see 14.5.1), and hay production is predicted to increase by 270% in the northwestern Great Plains by 2050 (Sleeter et al. 2012), which will likely alter raptor distribution and abundance. Expansion of invasive plant species, like cheatgrass, also creates a monoculture not conducive to prey habitat needs and increases wildfire frequency (Vilà et al. 2011; Bachen et al. 2018), which in turn affects abundance and reproductive rates of raptors.

Habitat conversion in arid rangelands can change the complexity of species richness, ecological diversity, and functional diversity of raptors (Tinajero et al. 2017). Increasing agricultural area can decrease functional diversity, or the component of biodiversity that influences ecosystem dynamics, stability, and ecosystem functioning (Tilman 2001). Because most raptor territories are in areas of complex habitat structure, shifts towards increasing agriculture reduce this complexity and favors more generalist species (Tinajero et al. 2017). Like other birds, raptor size and diet specificity appear to be the most important factors tied to tolerance of modified environments, with larger and more specialized species being more at risk (Sekercioglu 2012; Tinajero et al. 2017).

14.7.3 Energy Development

Unlike agricultural conversion that directly replaces habitat, energy development poses different challenges for avian predators through increased fragmentation and human presence (Shaffer et al. 2019). In areas of oil and gas development where vertical structures become available, species with increased tolerance of human disturbance at nest sites can sustain, or increase, in abundance (e.g., common ravens). Further, as fragmentation and human traffic increases, non-native plant species like cheatgrass can increase in abundance and further exacerbate these changes to prey habitat and subsequent raptor communities (see above).

Wind development across rangelands has the potential for significant impacts on raptor species, particularly golden eagles (Katzner et al. 2017; Millsap et al. 2022) due to the direct mortality of raptor collisions with turbine blades (Pagel et al. 2013). This new energy sector is poised to rapidly increase across rangelands due to a variety of factors, including increases in direct mortality, habitat fragmentation, human presence/vehicles, and power distribution.

Power distribution (e.g., power and transmission lines) infrastructure is another significant anthropogenic feature affecting occurrence and survival of avian predators in rangelands (Bedrosian et al. 2020). Distribution poles for water pumps and other power needs provide both perch and nesting sites in landscapes that would otherwise be devoid of vertical structure. Legacy distribution poles that were constructed before the *Avian Power Line Interaction Committee* guidelines (APLIC and USFWS 2005) have higher risk for electrocutions for large raptors. Similarly, transformers at dead-end poles used for water pumps that are unprotected also pose significant risk of electrocution due to exposed wiring. A bird, while landing or taking off, is at risk of touching two exposed energized parts that will cause electrocution. Further, a raptor may catch fire during electrocution and fall to the ground below the pole, causing a wildfire.

14.8 Conservation and Management Actions

14.8.1 *Loss and Fragmentation of Rangeland*

Similar to most rangeland wildlife, habitat change is the underlying force for most avian predator conservation issues in rangelands. Conversion of native habitats (e.g., to agriculture or invasive plant monocultures) and fragmentation from anthropogenic development both alter prey population dynamics and avian predator occupancy and abundance. The shift from low intensity use, such as livestock production, to higher intensity uses like oil and gas development have cumulative negative impacts on raptor species that require large territories to meet their survival and demographic requirements. Most shifts in habitat and anthropogenic use are trending to favor more generalist avian predators with a tolerance for human alterations across the landscape. More specialized raptors that require large expanses of habitat with little human use are becoming increasingly at risk. The most cost-efficient management is to protect the highest priority habitats, in other words, conserve large intact contiguous rangelands. Although restoration activities are commendable, for many avian predators that rely on rangelands the large spatial scale needed often makes full habitat restoration cost prohibitive.

14.8.2 *Predator Management*

Predator communities in rangelands have been altered due to human-induced habitat change and anthropogenic subsidies pose the greatest management challenge for sensitive prey species. For example, in the Chihuahuan Desert, human-provided subsidies of food, water, and nest sites has caused a significant increase of common ravens (Kristan and Boarman 2007). Concurrently, desert tortoise populations have been declining from habitat loss, disease, and other perturbations at such a rate that has caused them to become a federally listed endangered species. Because common ravens are very successful generalists, their increased abundance in tortoise habitat has led to greater predation on young tortoises (Kristan and Boarman 2003). These two independent factors have now led to a significant ecosystem conflict for two federally protected species on opposite population trajectories. Similar conflicts with ravens are widespread in greater sage-grouse sagebrush rangelands and has resulted in raven control efforts to mitigate increased predation pressure on grouse nests and chicks (Dinkins et al. 2016). Across the West, USDA Wildlife Services objectives are to control > 11,000 and displace > 125,000 ravens a year for livestock and sensitive species conflicts (https://www.aphis.usda.gov/aphis/ourfocus/wildlifedamage/SA_Reports/SA_PDRs). While these control actions may help local-level issues temporarily, they fail to address the ultimate cause of increasing raven populations: habitat alterations by humans.

Predator control has been a common management action to limit human-subsidized avian predator species and may seem less challenging compared to habitat conservation or restoration. However, studies have shown that direct control may reduce raven abundance for short periods in localized areas (Coates et al. 2007; Dinkins 2013), but the effectiveness of long-term suppression on management objectives (i.e., benefits to livestock and/or prey species) has yet to be demonstrated. Moreover, adult breeding ravens are the cohort most often occupying native rangelands with at-risk species and tend not to use subsidies during the breeding period (Bui et al. 2010; Harju et al. 2018). On the other hand, lethal control efforts are largely conducted in areas with high raven concentrations, such as roosts, landfills, and areas with other subsidies, to increase efficiency and effectiveness of the control efforts. However, breeding individuals may rarely be targeted due to their wariness of humans and their relatively reduced use of these subsidies (Harju et al. 2018).

Similar management efforts have occurred, and are continuing, to mitigate sheep predation by golden eagles (see 14.5.2). While eagle relocations have not been successful, some management actions have been, including installation of netting over lambing pens, using “scarecrows” on ridges where lambs bed for the night, removing dead livestock and other potential eagle attractants, and the use of guard dogs all have helped minimize or curtail eagle-lamb depredations (O’Gara and Rightmire 1987).

14.8.3 Management of Direct and Indirect Mortality

A major management objective to benefit raptor, corvid, and vulture populations in rangelands should include reducing anthropogenic-caused mortalities, including illegal persecution, vehicle strikes, turbine collisions, electrocutions, and poisoning. Road-killed ungulates should be moved at least 12 m from roadways to reduce raptor-vehicle collision risk when scavengers are feeding on roadkill (Slater et al. 2022). Lead-free ammunition should be used for both big-game, upland and varmint hunting to reduce secondary lead poisoning in raptors (Haig et al. 2014). Recent models of risk have been completed across the western rangelands as a function of power pole density (Dwyer et al. 2020) to help inform mitigation efforts to retrofit power poles in areas of high eagle breeding density. Retrofitting of power poles and transmission equipment can significantly reduce risk of electrocution can significantly reduce mortality risk if done correctly (Dwyer et al. 2015; Dwyer et al. 2017). Impacts from rodenticide poisoning can be avoided by discontinuing use in important habitats of raptors (Herring et al. 2017). Additionally, chemicals used to euthanize livestock are known to kill eagles (Viner et al. 2016). Poisoning by euthanasia agents can be avoided by burying, cremating, covering, or otherwise disposing of carcasses such that they are not available to scavengers. Management to benefit raptor populations in rangelands should include conserving and reducing disturbance to nesting and roosting habitats, following best practices energy development and other infrastructure, education to reduce human persecution, and conservation of native vegetation communities that support populations of prey species.

14.8.4 Habitat Management

Artificial nesting structures have been regularly used to increase nesting density and success for ground-nesting raptors, like ferruginous hawks and burrowing owls (Fig. 14.1). Because of the vulnerability of ground nests, increased traffic, human presence, noise from hunting/shooting activities, and land alterations have caused lower reproductive success. Nesting on anthropogenic structures has been linked to increased nest success and offers a mitigation tool in areas with at-risk populations (Wallace et al. 2016a, b). Artificial nesting platforms may also serve to reduce potential electrocutions of raptors when nesting on power poles. This management technique has been used successfully to relocate at risk ferruginous hawks and golden eagles (Kemper et al. 2020; G. McKee, personal communication). Similarly, providing artificial burrows for burrowing owls may help maintain and bolster populations in and adjacent to areas with habitat conversion or loss of burrowing mammals (Moulton et al. 2006; Menzel 2018). Conversely, nesting on anthropogenic structures has been an increasing problem for predators in conflict with sensitive species, like common ravens. Ravens regularly nest on human structures but will not nest on the



Fig. 14.1 Example of a ground nest built by a ferruginous hawk in western Wyoming (left) and an elevated artificial nesting structure in the same area (right). Photo credits: author

ground. While managing to reduce raven occurrence and abundance in rangelands through direct control the same managers could simply eliminate raven nest materials before eggs are laid, which would not violate the MBTA.

Recent conservation efforts on rangelands have been shifting to focus on identification and protection of priority habitats. The best example of this is not for raptors, but for greater sage-grouse. The Core Area Policy in Wyoming, for example, is designed to restrict development in the areas that host the largest number of breeding birds (Wyoming Executive Order 2019-3). The heart of this strategy is to identify and conserve the smallest areas that protect the largest number of birds. Similar efforts have been underway for golden eagles across their western range due to at-risk populations and the novel threat of increasing wind development in key eagle habitat (e.g., Dunk et al. 2019). Like the core area concept, protecting areas that host dense populations of breeding and wintering eagles will have disproportionately larger conservation benefits. For example, if 50% of all golden eagle nests in a state are located on only 10% of the landscape, then protecting that 10% will have greater benefit than conserving the other 90% of the state. With the priority area concept, it is extremely important to understand the entirety of a species' habitat requirements prior to delineating specific areas. For example, for multiple rangeland wildlife species managers have focused on breeding habitats while largely ignoring winter habitat or areas necessary for seasonal movement or genetic connectivity. For raptors, understanding migratory routes and seasonal ranges has been nearly impossible. But the contemporary advancement in tracking technologies for birds has largely filled this knowledge gap and we can now accurately assess habitat use and needs of migratory species. Because many rangeland raptors have intercontinental migratory and seasonal habitats, continued collaboration among countries, agencies, and other appropriate entities is essential to conserve the year-round habitat needs. A key example of this connectivity and need for international conservation of rangeland raptors is the Swainson's hawk, where pesticide use in South America in the

1990s threatened the population persistence of this species in North America and international efforts were successful in managing and largely eliminating this threat (Goldstein et al. 1999).

Prioritizing habitat conservation and protection prior to disturbance, especially direct habitat loss and fragmentation, will be key to conserving the long-term ecology of rangelands and is much simpler and less expensive than trying to restore degraded and altered habitats. Identifying and prioritizing areas of largely undisturbed intact habitat is critical for rangeland species due to limited remaining resources and the need of many species for large intact home ranges. Continuing low-density human use of rangelands, from a mix of livestock production, large ranches, and public lands, instead of increasing fragmentation from energy development and other anthropogenic uses, will be vital to maintaining biodiversity and ecological function within western rangelands.

14.9 Research Needs

There are many aspects of avian predator ecology that remain understudied. Most population status and trend estimates of raptors could be significantly improved. More information is needed on prey populations across rangelands and how to increase their populations. The complex and compounding relationship between changing prey density, climate change, and the interaction with avian predators needs further research. There is an increasing need for research concerning plague outbreaks in prairie dog populations and other raptor disease concerns like avian influenza and West Nile virus. The effects of both livestock grazing and vegetation treatments meant to support livestock production on raptor abundance and productivity on rangelands needs further attention. Research focusing on the interaction of grazing intensity, human presence, small mammal abundance, and the avian predator guild is currently lacking.

As in most regions, climate change has significant potential to alter rangeland systems, including avian predators that are associated with rangelands. As rangelands dry out with continued droughts, anthropogenic subsidies will become increasingly important to manage. Increasing fire frequency may hinder some rangelands (e.g., sage-steppe), while potentially benefiting others (e.g., grasslands). Heat-stress has also been shown to directly affect home range size and productivity of some rangeland raptors (Braham et al. 2015; Kochert et al. 2019). Secondary effects on seasonal shifts of prey (e.g., hibernation emergence or reproduction) and those effects on nesting raptors remain unknown.

Management actions centered on predator reduction still need more critical evaluation on their success, cost–benefit, scalability, and long-term success. More alternative actions, particularly non-lethal techniques like nesting deterrence options, need to be developed. Some ideas could be assessed, such as taste-aversion in corvids for grouse management, reducing anthropogenic nesting substrate and subsidies for generalist species, livestock herd protections (e.g., scarecrows for eagles), roadkill

removal to reduce winter eagle abundance, and non-lethal control options. While there are situations where lethal control methods need to be employed, there is a need to understand the efficacy and efficiency of lethal control methods and non-target impacts.

Finally, new and emerging threats to rangelands will continue to increase, further reducing and fragmenting native rangelands. Understanding and mitigating effects prior to these disturbances will be critical in maintaining raptor populations in rangelands. For example, the renewable energy demands in the U.S. is likely to lead to an increase in wind power development and biofuels. Wind development is increasingly more prominent in western rangelands and can be a significant risk to raptors from direct collisions and habitat alteration. Understanding and prioritizing the entire landscape for raptors is essential for long-term management through identification and protection of critical habitats. Further, more compensatory mitigation options are needed to offset any losses from this development since power pole retrofitting to reduce electrocutions is the only currently accepted management action to offset eagle mortalities. Other options, such as using lead-free ammunition for hunting, road-kill removal, and breeding habitat enhancements will all benefit rangeland raptor management. Prioritizing and conserving critical and key habitats for all sensitive species, including, but not limited to raptors, and all life history phases for each species will greatly enhance management decisions for the multiple uses and threats the future rangelands will face.

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