Jackrabbits

Biology of Jackrabbits (*Lepus* spp.) as Prey of Golden Eagles (*Aquila chrysaetos*) in the Western United States

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U.S. Fish and Wildlife Service
Regions 1, 2, 6, and 8
Western Golden Eagle Team

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Summary

Jackrabbits (*Lepus* spp.) are among the most important prey for golden eagles (*Aquila chrysaetos*) in the western United States. Black-tailed jackrabbits (*L. californicus*) are typically one of the most numerous prey in the diets of western golden eagles. White-tailed jackrabbits (*L. townsendii*) are among the top prey in portions of the Great Plains. Black-tailed and white-tailed jackrabbits may be key prey for golden eagles because they are optimal-sized; relatively well distributed and abundant; and occur in the kinds of open habitats favored by hunting golden eagles. Jackrabbit abundance and availability influence golden eagle populations in a variety of ways, including: dietary breadth; geographic distribution; density and abundance; mortality; reproduction; habitat selection; and migration.

Other leporids (family Leporidae) are important prey for golden eagles but are not discussed in this account. Cottontail rabbits (*Sylvilagus* spp.) frequently occur in the diets of western golden eagles and are discussed in a separate account (cottontails account). Snowshoe hares (*L. americanus*) are a key prey species for golden eagles in Alaska, which is outside the area considered in these accounts (McIntyre and Adams 1999; McIntyre and Schmidt 2012). Other jackrabbit species (*L. alleni* and *L. callotis*) in North America have relatively limited distributions (Simes et al. 2015) and have not been identified as important prey for golden eagles.

Black-tailed jackrabbits occur across most of the West, particularly in the Great Basin, California, and the Southwest. The white-tailed jackrabbit primarily occurs in the northern Great Basin and Great Plains. Both species generally occur in open habitats, such as shrub-steppe, prairies, desert grasslands, and agricultural areas. Both black-tailed and white-tailed jackrabbits tend to occur in areas with a mix of open vegetation, such as grasses and forbs, and more densely canopied vegetation, such as shrubs and tall weeds. Open areas used by jackrabbits may enable detection and escape from predators and typically contain herbaceous plants preferred as food, while shrubs provide cover from weather and predators and a source of food during times of year when succulent vegetation is unavailable.

Jackrabbits are known for their dramatic population fluctuations, though few studies have been conducted for a duration sufficient to capture a complete jackrabbit population "cycle". Black-tailed jackrabbits in the northern Great Basin fluctuate at approximately 7–11 year intervals. Population densities during jackrabbit irruptions may be tens or even hundreds of times greater than during population lows. Golden eagle behavior and demography can be strongly affected by jackrabbit population fluctuations.

Jackrabbit abundance and population fluctuations are influenced by a variety of environmental factors. Population die-offs may be driven by a suite of density-dependent factors, including parasites and diseases, food availability, and predators. Jackrabbit abundances can also be strongly affected by human hunting or population control measures, such as poisoning. Jackrabbits shot with lead bullets or poisoned are typically left in the field and may be a source of secondary poisoning for golden eagles, which often consume carrion.

Both black-tailed and white-tailed jackrabbits are globally and nationally ranked as being of low conservation concern. However, black-tailed jackrabbits may be declining or at risk of declining in some northern portions of their range. White-tailed jackrabbits may be declining rangewide, are a focus of considerable conservation concern in the western portion of their range, and have apparently been extirpated from some eastern parts of their range. Declines of both species are thought to be largely caused by loss and degradation of native shrublands and grasslands, including conversion to agricultural land, overgrazing by livestock, invasive plants, and altered fire regimes.

Habitat maintenance and enhancement for jackrabbits could be a valuable tool for conserving golden eagles, but little is known about how jackrabbits respond to management activities. At broad scales, managing jackrabbit habitat to benefit golden eagles largely depends on proper management of livestock grazing to avoid depleting ranges; preventing or reducing the spread of invasive plants that compete with plants used for food and cover; and reducing the occurrence of large wildfires that destroy habitat. Research has indicated that these factors negatively impact jackrabbits and golden eagle populations that rely on them. Climate change is an additional, emerging threat in these ecosystems and could cause tremendous changes to the quality and distribution of jackrabbit habitat. All of these factors are also threats to an array of shrub-steppe and grassland ecosystems and associated species, suggesting that jackrabbit management can be linked to existing conservation plans for imperiled landscapes and species.

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Importance to Golden Eagles

Occurrence in Golden Eagle Diets

Jackrabbits (*Lepus* spp.) are among the most commonly identified prey of breeding golden eagles (*Aquila chrysaetos*) in the western United States (U.S.). Bedrosian et al. (2017) synthesized data concerning the breeding season diets of golden eagles within 45 study locations in the conterminous western U.S., southern Canada, and northern Mexico. Based on the percentage of identified prey individuals, jackrabbits were one of the top three breeding season prey taxa for golden eagles in 39 of 45 (87%) studies (Figure 1). Black-tailed jackrabbits or unidentified jackrabbits were among the top three prey in 18 of 25 (72%) diet studies in intermountain basin shrub-steppe. Black-tailed jackrabbits were the most numerous prey in all 6 diet studies conducted in Southwest deserts. Additionally, black-tailed jackrabbits were among the primary prey in at least 1 study in most other ecoregions within their range. White-tailed jackrabbits (*L. townsendii*) were the first or second most numerous prey in golden eagle diets in 3 of 4 studies in the Great Plains of northeastern Wyoming and southeastern Montana. White-tailed jackrabbits were also among the top three prey species in Wyoming shrub-steppe (3 studies) and Rocky Mountains (1 study) ecosystems. Overall, research indicates that black-tailed jackrabbits are one of the golden eagle's primary breeding season prey across much of the western U.S., while white-tailed jackrabbits are primary prey in Wyoming and Montana (Figure 1). Bedrosian et al. (2017:356) stated that "reports of primary prey other than jackrabbits in the diet may indicate depressed or absent populations of jackrabbits in those ecoregions."

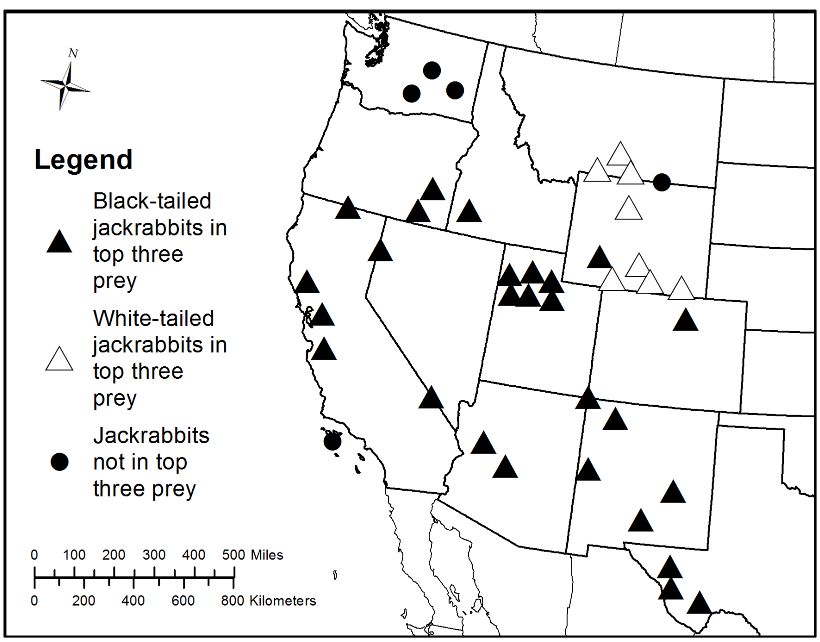

Figure 1: Locations of studies in which black-tailed or white-tailed jackrabbits were in the top three breeding season prey taxa for golden eagles based on percentage of identified prey individuals (based on Bedrosian et al. 2017).

The limited available information indicates that jackrabbits are also important prey for golden eagles during the nonbreeding season. Jackrabbits and/or cottontails (*Sylvilagus* spp.) were found in the stomachs and crops of 45% of golden eagles collected during January–March across multiple states (Arnold 1954). In southwestern Idaho, golden eagles took black-tailed jackrabbits during 45% of prey captures recorded during the nonbreeding season (Marzluff et al. 1997). In western Utah, Edwards (1969) found that both golden eagles and bald eagles (*Haliaeetus leucocephalus*) primarily relied on black-tailed jackrabbits as prey during winter. He was unable to distinguish between pellets from the two eagle species, which were active in the same areas, but found that 98% of pellets contained black-tailed jackrabbits. In Montana, white-tailed jackrabbits were found in 58% of stomachs of golden eagles collected in March (Woodgerd 1952). In northeastern Wyoming, white-tailed jackrabbits composed 45% of prey numbers in pellets during mid-November to mid-April (Hayden 1984).

Influence on Golden Eagles

Jackrabbits directly or indirectly influence golden eagles in a variety of ways, including: dietary breadth (Bedrosian et al. 2017); density and abundance (Smith and Murphy 1979; Kochert 1980; Craig et al. 1984; Oakleaf et al. 2014); mortality (Kochert 1980; Heath and Kochert 2016); reproduction (Reynolds 1969; Millsap 1978; Thompson et al. 1982; Steenhof et al. 1997; Oakleaf et al. 2014; Heath and Kochert 2016); habitat selection (Marzluff et al. 1997); and migration (Hoffman and Smith 2003, 2005).

Based on their extensive review of golden eagle diet research (see Occurrence in Golden Eagle Diets), Bedrosian et al. (2017) concluded that breeding golden eagles in the conterminous western U.S. show a general preference for jackrabbits and cottontails. Furthermore, they found that the breadth of golden eagle diets in the West appears to be largely determined by the percentage of jackrabbits and other leporids in the diet.

Some golden eagle populations respond to jackrabbit population fluctuations through changes in density or abundance. Smith and Murphy (1979) reported that a raptor community in central Utah, including golden eagles, had higher breeding season densities during years with higher numbers of black-tailed jackrabbits. In southeastern Idaho, Craig et al. (1984) found more active golden eagle nests during a study period with high black-tailed jackrabbit numbers than during a previous period with low jackrabbit numbers. A dramatic decline in abundances of nesting golden eagles in Wyoming may have been related to a statewide crash in leporid populations (Oakleaf et al. 2014). Research in southern Idaho indicated that wintertime densities (Kochert 1980) and abundances (Craig et al. 1984) of golden eagles were positively associated with jackrabbit population fluctuations. The abundance of golden eagles during winter in southeastern Idaho was 16 times higher during a period of high black-tailed jackrabbit numbers than during a period of low jackrabbit numbers (Craig et al. 1984).

Population fluctuations of jackrabbits could also influence golden eagles by indirectly contributing to mortality. In southwestern Idaho, Kochert (1980) found that the incidence of golden eagle electrocutions on power lines, a major source of mortality for the species (Kochert et al. 2002; USFWS 2016), was positively correlated with golden eagle densities during mid-winter, which were in turn positively related to densities of black-tailed jackrabbits. Higher densities of jackrabbits could also increase golden eagles' secondary exposure to lead, which is another source of mortality (Craig et al. 1990; Kochert et al. 2002; Stauber et al. 2010; Herring et al. 2017). Human hunters can kill very large numbers of jackrabbits and often leave the carcasses in the field (Flinders and Chapman 2003). Eagles may feed on dead jackrabbits as carrion and thereby ingest lead ammunition. Golden eagles could also be injured or killed by cars while feeding on road-kill jackrabbits (USFWS 2016). Golden eagle mortality is also negatively related to availability of jackrabbits. In southwestern Idaho, golden eagles consumed fewer black-tailed jackrabbits and more rock pigeons (*Columba livia*) and other alternative prey species after major fires burned jackrabbit habitat in the study area (Heath and Kochert 2016). Greater consumption of rock pigeons increases the probability that young eagles will contract trichomaniasis (*Trichomonas gallinae*); a parasitic infection that is typically fatal (Amin et al. 2014; Dudek and Heath 2015).

Reproduction by golden eagles was strongly and positively related to densities of black-tailed jackrabbits during a 23-year study in southwestern Idaho (Steenhof et al. 1997). During years with higher winter densities of jackrabbits, a higher percent of golden eagle pairs laid eggs, a higher percent of laying pairs were successful, laying pairs had earlier hatching dates, pairs fledged more young, and brood sizes at fledging were larger. Other studies have likewise found evidence of a positive relationship between golden eagle reproduction and jackrabbit numbers (e.g., Reynolds 1969; Millsap 1978; Thompson et al. 1982; Jenkins and Joseph 1984; Oakleaf et al. 2014; Heath and Kochert 2016; Preston et al. 2017). For example, in southeastern Oregon, Thompson et al. (1982) reported that the percent of golden eagle breeding territories that fledged at least one young was higher during years with higher apparent numbers of black-tailed jackrabbits and lower during years with lower jackrabbit numbers. Oakleaf et al. (2014) noted that a low in golden eagle reproduction in Wyoming corresponded with low counts of jackrabbits and cottontails, while 4–6 times as many eagles were fledged during years of high leporid counts.

The habitat associations of jackrabbits may influence the golden eagle's habitat selection. Golden eagles in southwestern Idaho selected shrub habitats at multiple spatial scales (Marzluff et al. 1997). Shrub habitats were likely selected by golden eagles due to their use by black-tailed jackrabbits, which are the golden eagle's primary prey in that area (Knick and Dyer 1997; see Habitat Associations).

Golden eagle migration may be influenced by fluctuations in jackrabbit populations. Record-high counts of migrating adult golden eagles in the Intermountain Flyway during the mid-1980s and mid-1990s corresponded to periods of very low jackrabbit abundance in the region (Hoffman and Smith 2003, 2005). These periods were also preceded by multi-year drop in counts of migrating immature eagles. Hoffman and Smith (2003, 2005) suggested that periods of low nesting success during jackrabbit population crashes increase the likelihood that adult eagles will migrate.

Prey Species Information

Physical Description

Jackrabbits, like other leporids, have long ears and large hind legs (Flinders and Chapman 2003). The black-tailed jackrabbit has gray-brown pelage, a black dorsal stripe on its tail and rump, and long black-tipped ears (Best 1996; Flinders and Chapman 2003). In contrast, the white-tailed jackrabbit has a white tail and lacks a prominent dark stripe (Lim 1987; Flinders and Chapman 2003). White-tailed jackrabbits have gray-brown or yellowish pelage during summer and are paler during winter (Flinders and Chapman 2003). They turn completely white during winter in areas with persistent snow, such as at higher elevations and in northern portions of their range (Nelson 1909; Lim 1987; Flinders and Chapman 2003). White-tailed jackrabbits are generally larger than black-tailed jackrabbits and the females of both species are, on average, slightly larger than males (reviewed in Lim 1987 and Flinders and Chapman 2003). Mature black-tailed jackrabbits are 18–25 inches (in) (465–630 millimeters [mm]) in total length and weigh 3.3–7.7 pounds (lbs) (1.5–3.5 kilograms [kg]) (reviewed in Best 1996 and Flinders and Chapman 2003). Adult white-tailed jackrabbits weigh 5.5–11 lbs (2.5–5 kg) and are 18–21 in long (560–660 mm) (reviewed in Lim 1987 and Flinders and Chapman 2003). Jackrabbits are considered optimal-sized prey for golden eagles (Watson 2010; Schweiger et al. 2015).

Ecological Roles

Jackrabbits and other leporids perform important ecological roles. For example, they can influence the distributions of plant species through selective herbivory (Vorhies and Taylor 1933; McAuliffe 1988; Gibbens et al. 1993; Roth et al. 2007) and seed dispersal (Riegel 1941; Timmons 1942; Brown 1947; Flinders and Hansen 1972). Jackrabbits are crucial sources of food for a variety of avian, mammalian, and reptilian predators (Vorhies and Taylor 1933; Flinders and Chapman 2003). Jackrabbit population densities influence the behavior and population vital rates of golden eagles (e.g., Steenhof et al. 1997; see Importance to Golden Eagles) and other predators (e.g., Smith et al. 1981; Craig et al. 1984; MacCracken and Hansen 1987; Knick 1990).

Distribution

The distributions of black-tailed and white-tailed jackrabbits widely overlap each other, as well as that of breeding golden eagles (Kochert et al. 2002; Figure 2). Black-tailed jackrabbits are the most widespread and common jackrabbit in the western U.S. (Nelson 1909; Flinders and Chapman 2003). They occur from Idaho and Washington south into central Mexico, and from western Arkansas and Missouri to the Pacific Coast (reviewed in Best 1996). Their elevation range is from below sea level to about 12,300 feet (ft) (3,750 meters [m]) (reviewed in Best 1996). White-tailed jackrabbits occur in the northern portion of the western U.S.; across the Great Plains and northern Great Basin and west into the Cascade Mountains and Sierra Nevada (reviewed in Lim 1987). They range in elevation from about 100 ft (30 m) above sea level to over 14,000 ft (>4,270 m) (reviewed in Lim 1987).

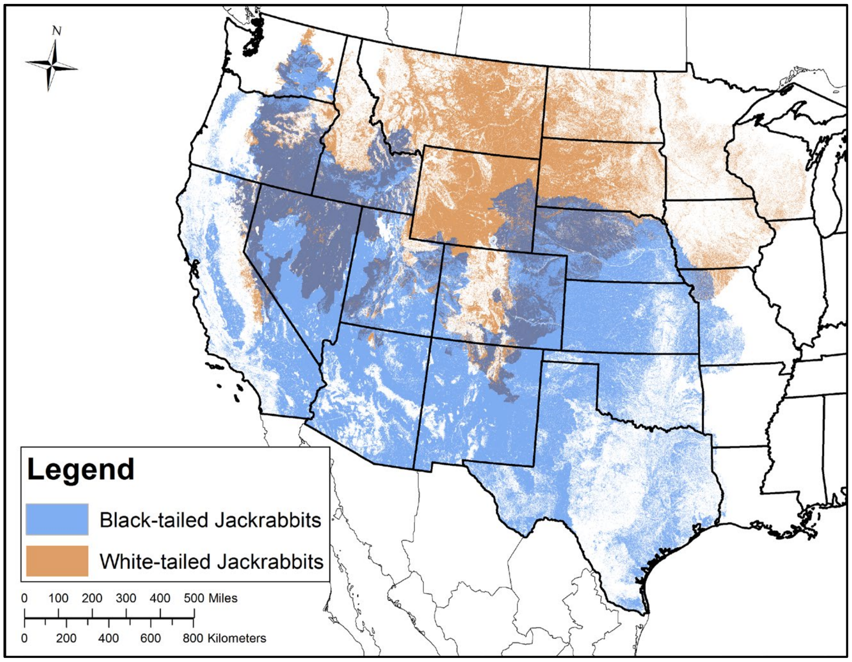

Figure 2: Distributional models of habitats suitable for occupation by black-tailed and white-tailed jackrabbits (USGS-GAP 2011).

Habitat Associations

Black-tailed jackrabbits occur in grasslands, shrublands, deserts, agricultural areas, and rangelands across the western U.S. (reviewed in Flinders and Chapman 2003 and Simes et al. 2015). In the Great Basin, they are often found in vegetation communities dominated by sagebrush (*Artemisia* spp.), greasewood (*Sarcobatus vermiculatus*), or shadscale (*Atriplex confertifolia*) (reviewed in Flinders and Chapman 2003; e.g., Gross et al. 1974). In Kansas and Colorado, black-tailed jackrabbits occur in short-grass and mixed-grass prairies (Tiemeier 1965; Flinders and Hansen 1975). In Arizona, they are found in habitats dominated by creosote (*Larrea tridentata*), mesquite (*Prosopis* spp.), and cacti (e.g., *Carnegiea gigantea, Opuntia* spp.*, Cylindropuntia* spp.) (Vorhies and Taylor 1933; Brown and Krausman 2003). Black-tailed jackrabbits in southeastern New Mexico occupy desert shrub communities with mesquite, snakeweed (*Gutierrezia* spp.), and soap-tree yucca (*Yucca elata*) (Davis et al. 1975). In California, the species occurs widely in open and semi-open vegetation, including desert shrub, agricultural areas, and oak (*Quercus* spp.) savanna (Orr 1940; Lechleitner 1958; Caro et al. 2000).

White-tailed jackrabbits inhabit a variety of ecosystems, including prairies and other open grasslands, sagebrush steppe, alpine tundra, and agricultural fields (reviewed in Flinders and Chapman 2003 and Simes et al. 2015). In the Wyoming Basins, modeled occurrence of white-tailed jackrabbits was associated with cover of sagebrush and grassland at relatively small modeling scales (0.17 mi [0.27 km] and 0.34 mi [0.54 km] diameter, respectively), and with salt desert shrubland at a larger modeling scale (1.9 mi [3.0 km]) (Hanser et al. 2011). In the Basin and Range and Columbia Plateau, white-tailed jackrabbits may be primarily confined to upper montane slopes (Simes et al. 2015). Studies have found seasonal changes in the habitat associations of white-tailed jackrabbits. In eastern Washington, white-tailed jackrabbits were located on dry, hilly bunchgrass sites during summer and in lower sagebrush valleys during winter (Dalquest 1948; Clanton and Johnson 1954). Early naturalists in California's Sierra Nevada observed similar patterns of white-tailed jackrabbits using open, higher elevation areas during summer and lower elevation sagebrush areas during winter (Orr 1940). In southern Colorado, white-tailed jackrabbits used grassland more than areas dominated by rabbitbrush (*Chrysothamnus* spp.) or sagebrush during summer and made little use of meadowland; whereas, during winter, they were found in nearly equal numbers in grassland and meadowland (Bear and Hansen 1966). During winter, white-tailed jackrabbits use areas where wind or terrain features keep snow from collecting at depths that impede foraging or traveling (Bear and Hansen 1966; Braun and Streeter 1968).

Optimal habitats for both black-tailed and white-tailed jackrabbits may contain a mix of open areas with herbaceous vegetation and denser shrub or grass cover (Orr 1940; Bear and Hansen 1966; Knick and Dyer 1997). Open patches of grass and other herbaceous vegetation provide food, visibility, and freedom of movement, whereas some shrub species provide a stable source of food, as well as cover from predators and weather (reviewed in Flinders and Chapman 2003 and Simes et al. 2015). Black-tailed jackrabbits primarily use open, grass-dominated habitats for feeding at night and retreat to the cover of denser shrubs or weeds during much of the day (Fautin 1946; Johnson and Anderson 1984). Bear and Hansen (1966) noted that white-tailed jackrabbits observed in open meadows or ridges had often flushed from adjacent tall shrubs. Although black-tailed jackrabbits are often positively associated with shrub cover (reviewed in Simes et al. 2015; e.g., Desmond 2004), open grasslands can provide suitable habitat, provided scattered shrubs or other densely canopied plants are available as cover (Lightfoot et al. 2010). In areas with dense, uniform shrub cover, herbaceous vegetation may be more limiting than shrub cover (MacCracken and Hansen 1982).

Black-tailed and white-tailed jackrabbits have overlapping habitat associations. However, black-tailed jackrabbits are more generally associated with shrubby vegetation communities, while white-tailed jackrabbits are more associated with grasslands and other open habitat types and occur at higher elevations more often than black-tailed jackrabbits (reviewed in Lim 1987 and Simes et al. 2015). These differences are particularly evident in areas in which the two species are sympatric (Lim 1987). For example, in the eastern Sierra Nevada of California, white-tailed jackrabbits were more frequently seen on high mountain slopes and ridges, while black-tailed jackrabbits were more often observed on the valley floor (Severaid 1950). Similarly, in a short-grass prairie in northeastern Colorado, white-tailed jackrabbits tended to select more sparsely vegetated upland habitats and black-tailed jackrabbits were found more frequently in denser lowland habitats (Flinders and Hansen 1975).

Diet

Jackrabbits are generalist herbivores with highly variable diets (reviewed in Flinders and Chapman 2003). The bulk of their diet consists of grasses and forbs during spring and summer and perennial shrubs during winter (reviewed in Flinders and Chapman 2003 and Simes et al. 2015). Seasonal shifts in the diets of jackrabbits are associated with changes in the availability and maturity of plant foods, particularly succulent vegetation (Vorhies and Taylor 1933; Sparks 1968; Fagerstone et al. 1980; Johnson and Peek 1984). Wild jackrabbits may obtain most of their water through their diet, rather than from standing water; particularly in arid regions (Hunter 1987; Flinders and Chapman 2003). Moreover, succulent plants are better assimilated in the digestive tracks of jackrabbits than dry, woody plants (Hansen 1972; Johnson and Peek 1984).

Black-tailed jackrabbits appear to select grassy habitats for foraging and then eat the available species, rather than selecting foraging areas in order to access particular grass species (Johnson and Anderson 1984). However, some grass taxa, such as, needle-and-thread (*Stipa comata*), dropseeds (*Sporobolus* spp.), gramas (*Bouteloua* spp.), and sedges (*Carex* spp.), substantially contribute to black-tailed diets in multiple geographic areas (Hayden 1966; Sparks 1968; Flinders and Hansen 1972; Flinders and Crawford 1977; Uresk 1978; MacCracken and Hansen 1984; Fatehi et al. 1988; Wansi et al. 1992; Daniel et al. 1993a). A variable and wide array of forbs occur in black-tailed jackrabbit diets. Forbs that have appeared in black-tailed jackrabbit diets in multiple studies or geographic areas include *Halogeton* spp., the Boraginaceae family, Spiderling (*Boerhavia* spp.), *Croton* spp., and Snakeweed (Vorhies and Taylor 1933; Griffing and Davis 1976; Westoby 1980; Johnson and Anderson 1984; MacCracken and Hansen 1984; Fatehi et al. 1988; Wansi et al. 1992; Daniel et al. 1993a). Shrubs consumed by black-tailed jackrabbits likewise vary among studies and geographic areas. Some important shrubs and cacti for the species include winterfat (*Krascheninnikovia* spp.), mesquite, rabbitbrush, sagebrush, soaptree yucca, and prickly pear cactus (*Opuntia* spp.) (Vorhies and Taylor 1933; Sparks 1968; Griffing and Davis 1976; Westoby 1980; Johnson and Anderson 1984; MacCracken and Hansen 1984; Wansi et al. 1992; Daniel et al. 1993a).

Crops depredated by black-tailed jackrabbits include barley, wheat (*Triticum* spp.), sorghum (*Sorghum* spp.), soybeans (*Glycine max*), alfalfa, wheatgrass, clover (*Trifolium* spp.), orchard trees, grape vines (*Vitis* spp.), vegetables, cotton (*Gossypium* spp.), lawn and pasture grasses, and ornamental trees and shrubs (reviewed in Fagerstone et al. 1980, Best 1996, and Flinders and Chapman 2003). Fagerstone et al. (1980) reported that barley and crested wheatgrass (*Agropyron cristatum*) were preferred foods of black-tailed jackrabbits in southern Idaho and constituted a large proportion of the diet. Lechleitner (1958) similarly found that young barley was a preferred food of black-tailed jackrabbits in California. Alfalfa can be a substantial component of black-tailed jackrabbit diets during late summer through winter (Sparks 1968; Flinders and Hansen 1972; Bickler and Shoemaker 1975).

Comparatively little is known about the diets of white-tailed jackrabbits. Studies in Colorado found that the species primarily consumed wheatgrass, winter wheat, sedges, legumes, summer cypress (*Bassia scoparia*), clover (*Trifolium* spp.), dandelion (*Taraxacum offinale*), Indian paintbrush (*Castilleja integra*), goosefoot (*Chenopodium* spp.), winterfat, rabbitbrush, and sagebrush (Bear and Hansen 1966; Flinders and Hansen 1971, 1972). In the Sierra Nevada of California, white-tailed jackrabbits apparently consumed creambush (*Holodiscus discolor*) in September and sagebrush during winter (Orr 1940). Crops such as wheatgrass, winterwheat, and alfalfa can be major components of white-tailed jackrabbit diets (Bear and Hansen 1966; Flinders and Hansen 1971, 1972; Brunton 1981).

Population Fluctuations and Densities

Jackrabbit populations can fluctuate dramatically, reaching plague-like densities in some years and crashing in others (reviewed in Flinders and Chapman 2003 and Simes et al. 2015). Reported densities for black-tailed jackrabbits have ranged from less than 25 per square mile (mi^2) (10/square kilometer [km^2]) to 492 per mi^2 (190/km^2) (Wooster 1935; Bronson and Tiemeier 1959; Gross et al. 1974; Eberhardt and Van Voris 1986). Differences between high and low population years approached 325 fold during a long-term study of black-tailed jackrabbits in the northern Great Basin (Bartel et al. 2008). However, lower amplitude population fluctuations may be more common (Gross et al. 1974; Eberhardt and Van Voris 1986; Bartel et al. 2008; Hernández et al. 2011). For example, differences between high and low years were in the range of 11:1 and 30:1 during 21 years of black-tailed jackrabbit monitoring in Utah (Eberhardt and Van Voris 1986). Relatively little is known about white-tailed jackrabbit population fluctuations (Simes et al. 2015). Reports of white-tailed jackrabbit densities have ranged from less than 8 per mi^2 (3/km^2) to 181 per mi^2 (70/km^2) (Mohr and Mohr 1936; Kline 1963; Rogowitz and Wolfe 1991); with a historical high report of at least 252–378 per mi^2 ($\geq$97-146/km^2), based on numbers killed by hunters in one area (Bailey 1926).

Broad, multiannual patterns in fluctuations have been recorded during long-term studies of jackrabbits (reviewed in Simes et al. 2015). Black-tailed jackrabbit populations in the northern Great Basin and neighboring areas fluctuate at approximately 7–11 year intervals (Eberhardt and Van Voris 1986; Steenhof et al. 1997; Bartel et al. 2008). Jackrabbit population fluctuations may often vary among localized areas, however, and lack sufficient regularity to be considered truly cyclic (Simes et al. 2015). This is particularly true in the southern portions of the black-tailed jackrabbit's range, where the species often exhibits lower amplitude and more variable population fluctuations than in the north; apparently due to greater spatial and temporal variation in environmental conditions (Simes et al. 2015).

Jackrabbit populations fluctuate seasonally, as well as multiannually. Seasonal fluctuations of jackrabbits reflect increased abundances due to reproduction in spring and summer, followed by often heavy mortality during winter. Black-tailed jackrabbits may often experience 50% or greater overwinter mortality (Gross et al. 1974; Bartel et al. 2008). High overwinter mortality rates may also be typical for white-tailed jackrabbits (Rogowitz and Wolfe 1991). The typical life span of white-tailed jackrabbits in Wyoming was less than 1 year and only 12% of animals collected by researchers were more than 1.5 years old (Rogowitz and Wolfe 1991).

Jackrabbit movements can complicate interpretations of demographic data and conclusions about population fluctuations (Bartel et al. 2008; Simes et al. 2015). Black-tailed jackrabbits in northern Utah moved an average of about 7 mi (11 km), most often during fall/winter and early spring, though movements were typically shorter (Smith et al. 2002). Even short distance movements can temporarily result in dense local concentrations of jackrabbits (French et al. 1965). Some jackrabbit populations seasonally migrate to and from traditional wintering areas, where snow cover is generally lower than in summering areas (Smith et al. 2002; Bartel et al. 2008). Jackrabbits can also respond to severe weather or climatic events with substantial changes in density (e.g., droughts: Bronson and Tiemeier 1958, 1959; snowstorms: Vorhies and Taylor 1933).

The causes of jackrabbit population fluctuations are poorly understood (Simes et al. 2015). Reproduction can be influenced by jackrabbit density (French et al. 1965) and other environmental factors, such as snow cover (Rogowitz 1992). However, mortality may have a larger effect on jackrabbit population fluctuations than reproduction (Wagner and Stoddart 1972; Bartel et al. 2008). Jackrabbit population fluctuations are likely influenced by a suite of density-dependent mortality factors, such as predation pressure, parasitism and disease, and forage availability, rather than driven by any single factor (Vorhies and Taylor 1933; Philip et al. 1955; Wagner and Stoddart 1972; Stoddart 1985; Simes et al. 2015; see Influences on Abundance).

Influences on Abundance

Parasites and Diseases

The effects of parasites and diseases on individual jackrabbits vary depending on the type and degree of infestation or infection. Botfly (*Cuterebra* spp.) infestations can weaken and distress jackrabbits and, since they are often concentrated around the eyes, can cause blindness, which potentially increases the risk of mortality (Vorhies and Taylor 1933; Philip et al. 1955). Other ectoparasites do not have such a strongly debilitating effect on jackrabbits, though some are vectors of diseases that can weaken or kill them (Flinders and Chapman 2003). Infection by tapeworms (Class Cestoda) could be a source of mortality in some jackrabbit populations. Tapeworm cysts are sometimes large or numerous enough to impair the function of organs, limbs, or the mouth, and can even completely fill the abdominal cavity (Vorhies and Taylor 1933; Lechleitner 1958; Lipson and Krausman 1988). Tularemia (*Francisella tularensis*) is a particularly virulent disease (Philip et al. 1955; Lechleitner 1959; McAdoo and Young 1980). McAdoo and Young (1980) stated that the mortality rate of jackrabbits with tularemia may reach 90%. Otherwise, diseases and parasites only directly cause mortality of jackrabbits in extreme cases and are unlikely to be primary causes of jackrabbit die-offs. However, parasitism and disease may contribute to die-offs as part of an array of density-dependent mortality factors (Vorhies and Taylor 1933; Philip et al. 1955).

Weather

Information about the potential influence of precipitation on jackrabbit population fluctuations is contradictory and is limited to one region. Fluctuations in black-tailed jackrabbit numbers during a 10-year period in the Chihuahuan Desert in northern Mexico were positively related to productivity of both grasses and forbs, which were in turn positively related to annual precipitation (Hernández et al. 2011). The researchers concluded that precipitation influenced jackrabbit numbers through effects on the availability of food. In contrast, a study during nearly the same time period but in a more northern portion of the Chihuahuan Desert (New Mexico) found no evidence of a relationship between black-tailed jackrabbit densities, plant production, and annual rainfall (Lightfoot et al. 2010). The authors of that study suggested that the availability of woody shrubs as a stable food source buffered jackrabbits in the area from short-term variation in rainfall. Further research of potential effects of precipitation on jackrabbit populations is necessary, particularly in light of climate change. Even small changes in precipitation could have dramatic and widespread effects on vegetation and natural disturbance patterns in arid and semi-arid regions of the U.S., where jackrabbits are among the most important prey for golden eagles (Brown et al. 1997; Wagner 1999; Neilson et al. 2005; Weiss and Overpeck 2005; see Management Considerations).

Predators

Jackrabbits are an important food source for many predators, including golden and bald eagles, hawks (*Buteo* spp.), great horned owls (*Bubo virginianus*), coyotes (*Canis latrans*), gray wolves (*C. lupus*), foxes (*Urocyon cinereoargenteus, Vulpes* spp.), martens (*Martes americana*), weasels (*Mustela* spp.), lynx (*Lynx canadensis*), bobcats (*L. rufus*), and rattlesnakes (subfamily Crotalinae) (reviewed in Lim 1987 and Best 1996). Coyotes may often be the primary predator of jackrabbits (Stoddart 1970; Flinders and Chapman 2003). Mortality of jackrabbits has been positively correlated with the density of coyotes; and coyotes, in turn, have responded to changes in jackrabbit abundance, both numerically and in terms of levels of predation on jackrabbits and other species (Vorhies and Taylor 1933; Clark 1972; Wagner and Stoddart 1972; MacCracken and Hansen 1987; Bartel and Knowlton 2005; Esque et al. 2010). Numbers of black-tailed jackrabbits have significantly increased in response to control programs for coyotes, further indicating that coyotes may limit jackrabbit populations (Vorhies and Taylor 1933; Wagner and Stoddart 1972; Henke and Bryant 1999). Predation could regulate jackrabbit populations as one of multiple density-dependent mortality factors, possibly including food supply (Hernández et al. 2011) and parasites and diseases (Vorhies and Taylor 1933; Philip et al. 1955). Predators may also influence densities of jackrabbits by driving them to use areas that contain or are nearby hiding cover, as well as suitable forage (Marín et al. 2003).

Control Programs

Jackrabbits can cause substantial damage to agricultural crops during population irruptions or when locally concentrated (Evans et al. 1970; Flinders and Chapman 2003). Jackrabbits are also considered pests by some ranchers because they compete with domestic livestock for forage (Vorhies and Taylor 1933; Currie and Goodwin 1966; Johnson 1979; Daniel et al. 1993a, Ranglack et al. 2015). However, the negative impacts of jackrabbits on livestock may be largely limited to early spring (Sparks 1968; Johnson 1979), and when jackrabbits are at high densities in rangelands already depleted by poorly managed livestock grazing (Johnson and Peek 1984; Daniel et al. 1993a).

Rabbit drives were a common control measure for jackrabbits during the late 19th and early 20th centuries (Palmer 1897; Johnson and Peek 1984; Flinders and Chapman 2003). During these drives, large numbers of people surrounded a tract of land and drove jackrabbits toward a central corral and clubbed them to death. This control method likely resulted in the death of millions of jackrabbits (e.g., greater than half a million in California alone during the late 1800s: Palmer 1897). Payment of bounties was another widespread early control method for jackrabbits. Jackrabbit bounties resulted in bankruptcy of some counties and apparently had no long-term effects on jackrabbit numbers so they were usually quickly repealed (McAdoo and Young 1980).

Organized group hunts are still used for controlling jackrabbit populations. During organized group hunts, hunters systematically walk parallel to each other and flush jackrabbits from cover (Flinders and Chapman 2003). Groups of hunters may cover the same transects several times in a weekend and could therefore, strongly affect local rabbit populations; particularly in states with no seasonal restrictions or bag limits on jackrabbit hunting (Flinders and Chapman 2003; see Appendix 1). Flinders and Chapman (2003) speculated that the combination of uncontrolled hunting and loss of native habitat may have interrupted jackrabbit population "cycles" in some areas.

Poison baits such as strychnine, sodium fluorocetare, zinc phosphide, and anticoagulant rodenticides have been extensively used to control jackrabbits (Evans et al. 1970; Best 1996; Flinders and Chapman 2003). Some of the poisons used to control jackrabbits also harm non-target species (Evans et al. 1970; Johnson and Peek 1984). For example, secondary exposure to anticoagulant rodenticides can cause serious injury or death of golden eagles and other predators that eat poisoned carrion or prey (Stone et al. 1999; Erickson and Urban 2004; Albert 2009; Herring et al. 2017).

Alternatives to direct lethal control exist for minimizing negative impacts of jackrabbits on agriculture and livestock without risking poisoning golden eagles and other predators. For example, buffer crops, such as potatoes or rye (*Leymus* spp., *Secale* spp.), which are relatively unattractive to jackrabbits for foraging, may be planted around more palatable and economically valuable crops (Lewis 1946; Fagerstone et al. 1980; Ganskopp et al. 1993). Evans et al. (1970) pointed out, however, that buffer crops are unlikely to successfully prevent crop damage when jackrabbit populations are at high levels. Research suggests that crop damage could also be minimized by planting large or uniformly shaped fields, which have less edge adjacent to jackrabbit cover than narrow or irregularly shaped fields of the same size (Westoby and Wagner 1973; Roundy et al. 1985). Damage might also be reduced by removing cover of shrubs and other densely canopied plants in areas adjacent to fields (Vorhies and Taylor 1933; Bronson and Teimeier 1958; Fagerstone et al. 1980; Johnson and Peek 1984); though this could be cost-prohibitive or have negative impacts on other wildlife (Johnson and Peek 1984). Minimizing competition between jackrabbits and livestock could potentially be achieved through a combination of conservative livestock grazing and relaxed or absent predator control (Vorhies and Taylor 1933; Taylor et al. 1935; Ranglack et al. 2015).

Recreational Hunting

Hunting jackrabbits is a popular activity in many regions of the U.S. (Flinders and Chapman 2003). Jackrabbits are not typically classified as game species by states so there are generally few, if any, hunting restrictions for them (Flinders and Chapman 2003; Appendix 1). Hunters are capable of killing large numbers of jackrabbits (e.g., Tiemeier 1965). Hunters usually kill jackrabbits purely for sport or as pests and leave them in the field (Flinders and Chapman 2003). Jackrabbits left by hunters may serve as a source of lead exposure for golden eagles and other wildlife (Platt 1976; Craig et al. 1990).

Habitat Loss or Modification

Agricultural land conversion has had mixed effects on jackrabbits (reviewed in Simes et al. 2015). Jackrabbits depredate agricultural crops and likely benefit from having succulent food available during portions of the year when grasses and forbs are dry or unavailable (see Diet). Black-tailed jackrabbits have partially or completely replaced white-tailed jackrabbits in many areas following land conversion to agriculture (reviewed in Simes et al. 2015). However, habitat loss to agriculture is one of the factors thought to be causing population declines of both species (WDFW 2015; see Population Status).

Encroachment and increased densities of trees and shrubs have contributed to large-scale degradation or loss of arid and semi-arid grasslands, shrublands, and savannas across the West (DeLoach 1985; Archer 1989; Miller and Rose 1999; Van Auken 2000; Miller and Tausch 2001). These changes have likely had mixed effects on jackrabbits, depending on whether they increase or decrease availability of shrub cover and palatable grasses and forbs (see Management Consideration). Exotic annual grasses have also replaced or degraded shrublands and grasslands within large portions of the western U.S. (Pellant and Hall 1994; Reid et al. 2008; Brooks et al. 2016; Pyke et al. 2016). These grasses can provide highly combustible, continuous fuel for fires, which can destroy large areas of jackrabbit habitat and negatively impact golden eagles (Knick and Dyer 1997; Kochert et al. 1999; Heath and Kochert 2016). See Management Considerations, for further discussion of these topics as they relate to conservation of jackrabbits and golden eagles.

Other Influences

Wildfires may impact jackrabbit populations through direct mortality, as well as through habitat loss and degradation; particularly when fires are large or have fast-moving fronts (Vorhies and Taylor 1933; Smith 2000). We are unaware of any estimates of direct mortality of jackrabbits from fires available at this time. However, we suspect that fire generally has larger and longer-lasting effects on jackrabbit populations through changes to habitat composition, structure, and ecological processes.

Best's (1996) literature review indicated that the number of black-tailed jackrabbit carcasses on highways have ranged from less than 1.6 per mi (1/km) in uncultivated areas of Kansas to about 208 per mi (130/km) in Idaho. Golden eagles may be attracted to highways to feed on jackrabbit road-kill, where they may then be at heightened risk of collision with vehicles or live power lines (USFWS 2016). Clearing dead jackrabbits and other carrion from roadsides can be used to reduce mortality of golden eagles and possibly as a compensatory mitigation action (USFWS 2013; Allison et al. 2017).

Population Status

The International Union for Conservation of Nature (IUCN 2016) ranks both black-tailed and white-tailed jackrabbits as species of "least concern". Similarly, NatureServe (2015) ranks both species as globally and nationally "secure". Few states in the western U.S. restrict hunting of jackrabbits or mention them in their Wildlife Action Plans or Conservation Strategies (Appendix 1). However, as described below, conservation concern exists for both species in some portions of their ranges (also see Appendix 1). Given their importance as prey, declines in the population sizes or distributions of jackrabbits could negatively impact golden eagles (see Importance to Golden Eagles and Management Considerations).

Black-tailed jackrabbits are generally well distributed and abundant, though they periodically exhibit natural population crashes (Flinders and Chapman 2003; Appendix 1). In the western U.S., they are primarily a focus of conservation concern in Montana and Washington (NatureServe 2015; WDFW 2015). Black-tailed jackrabbits in Washington are thought to be declining due to loss of shrub-steppe and grasslands to conversion to agriculture, overgrazing by livestock, and invasion by exotic annual grasses (WDFW 2015). Outside the West but within the golden eagle's winter range (Kochert et al. 2002), the status of black-tailed jackrabbits is of concern in Missouri and Arkansas (NatureServe 2015). The species is also noted as being potentially "at risk" in Nebraska (Schneider et al. 2011) and is a "focal species" in California (CDFW 2015). Research suggests that some black-tailed jackrabbit populations ranked as secure may merit greater concern. For example, black-tailed jackrabbits are declining in Kansas due to land conversion (Applegate et al. 2003); and the species could be declining in parts of the Great Basin and Southwest due to widespread loss of shrub habitat to exotic annual grasses and wildfire (see Management Considerations). Climate change is projected to exacerbate loss of native shrub and grass habitats in arid and semi-arid regions of the western U.S. and could therefore negatively affect black-tailed jackrabbits and golden eagles (see Management Considerations).

Despite the low conservation rankings for white-tailed jackrabbits at international and national levels, and throughout much of the West (Appendix 1), Simes et al. (2015:506) stated that "most sources agree that the species is largely declining across its range." The species is "presumed extinct" in Kansas, "imperiled" in New Mexico, "vulnerable/apparently secure" in Utah, and "imperiled/vulnerable" in Washington (NatureServe 2015). Outside the West, white-tailed jackrabbits are "presumed extinct" in Illinois and Missouri; "possibly extinct" in British Columbia, Canada; "imperiled" in Ontario, Canada; and "vulnerable" in Iowa (NatureServe 2015). White-tailed jackrabbits are listed as a "Species of Greatest Conservation Need" in Washington, a "sensitive species" in Oregon, a "Tier 2" species (remains important in light of population trends or habitat conditions) in Colorado, a "Tier II" species (at risk) in Nebraska (Schneider et al. 2011), and a "focal species" in California (CDFW 2015; CPW 2015; WDFW 2015; ODFW 2016). Declining populations and a contracting range in some portions of North America may be primarily due to habitat loss to agriculture and livestock grazing and increased competition with black-tailed jackrabbits (Simes et al. 2015).

Management Considerations

The U.S. Fish and Wildlife Service (2016:91; hereafter, "Service") stated that "potentially key factors for golden eagles are prey densities and the availability of nest sites near suitable prey populations." Jackrabbits are one of the most prevalent prey in golden eagle diets across much of the western U.S. and directly or indirectly influence golden eagles in a variety of ways, including population density, mortality, and reproduction (see Importance to Golden Eagles). Where they are primary prey, jackrabbits may even limit the number of golden eagle territories that the landscape can support (Kochert et al. 1999). Thus, maintaining or enhancing jackrabbit habitat could be a useful conservation tool for golden eagles. Enhancing availability of jackrabbits and other prey may be used to mitigate take of golden eagles, though standards for doing so have yet to be developed (USFWS 2013; Allison et al. 2017).

The Service noted that loss of foraging habitat for golden eagles can be caused by poorly managed livestock grazing, invasive vegetation, wildfire-caused habitat conversion, and climate change (USFWS 2016). These are also primary management issues for jackrabbits (this section; also see Influences on Abundance and Population Status). Both jackrabbits and golden eagles (Kochert et al. 2002) have broad geographic ranges and diverse habitat associations and diets, so management plans to address these threats should be tailored to specific regions and ecosystems. Ecoregional conservation strategies for golden eagles and their prey are available at https://www.fws.gov/westerngoldeneagle/.

Livestock Grazing

In late-seral desert grasslands, jackrabbits can benefit from livestock grazing that is heavy enough to alter competitive relationships between dry or uniformly dense, tall grass and other plants that provide more succulent forage, greater visibility for detecting predators, or better cover from heat and predators (Vorhies and Taylor 1933; Taylor et al. 1935; Taylor and Lay 1944; Daniel et al. 1993a, b; Nelson et al. 1997). Yet, overgrazing, particularly if accompanied by drought, can deplete ranges and contribute to declines in jackrabbit abundance (Vorhies and Taylor 1933; Taylor et al. 1935; Taylor and Lay 1944). A similar relationship could occur in late-seral grasslands in other parts of the western U.S. (e.g., in Kansas: Bronson and Tiemeier 1959). In short-grass prairie, however, habitat selection by black-tailed jackrabbits is probably not limited by tall, dense vegetation and the species was found to be more abundant in lightly or moderately grazed areas than in heavily grazed areas (Flinders and Hansen 1975). There is currently no published research about the direct effects of livestock grazing on jackrabbit abundance in shrub-steppe ecosystems, though poorly managed grazing can foster habitat changes that negatively impact jackrabbits and golden eagles, such as invasion by conifers or exotic annual grasses and altered fire regimes (see Fire and Invasive Plants). Rather than risk overgrazing, conservative grazing (e.g., 30–40% use of forage), or other strategic approaches to grazing, could be applied in some grasslands to maintain the mid-seral or mosaic habitat conditions prefered by black-tailed jackrabbits (Daniel et al. 1993b; Nelson et al. 1997); minimize competition between livestock and jackrabbits (Daniel et al. 1993a); obtain higher profits over the long-term (Holechek 1992; Holechek et al. 1999); and balance objectives for livestock and jackrabbits with other land management objectives (Holechek et al. 1982; Holechek 1991).

Fire and Invasive Plants

Exotic Annual Grasses

Millions of acres of shrublands and grasslands across the West have been invaded by cheatgrass (*Bromus tectorum*), red brome (*B. madritensis, B. rubens*), and other exotic annual grasses (Pellant and Hall 1994; Salo 2004). In western shrublands and grasslands, continuous fuel provided by annual grasses has fostered the spread of fires far larger than those that occur in areas dominated by native vegetation or that typified the pre-settlement period (Brooks and Pyke 2001; Keane et al. 2008; Balch et al. 2013; Brooks et al. 2016). Many areas of the West are now locked in a grass/fire cycle, wherein fire-adapted annual grasses facilitate fires, which kill sagebrush and other fire-intolerant native competitors, and thereby promote even greater spread of annual grasses (D'Antonio and Vitousek 1992; Brooks et al. 2004; Balch et al. 2013).

Fires during the 1980s and 1990s destroyed nearly half the native shrub habitat in the Morley Nelson Snake River Birds of Prey National Conservation Area (NCA) in southwestern Idaho, converting it to cheatgrass and other exotic annuals (Kochert and Pellant 1996; USDI 1996). These vegetation changes resulted in large-scale habitat loss for black-tailed jackrabbits, one of the primary prey species for golden eagles in the area (USDI 1996; Knick and Dyer 1997). The percentage of golden eagle pairs that successfully raised young significantly declined after major fires but then rebounded after a few years; apparently due to eagles switching to alternate foraging habitats and prey (Marzluff et al. 1997; Kochert et al. 1999; Heath and Kochert 2016). However, the number of golden eagle territories in the NCA has substantially declined since the mid-1970s (USDI 1996; Kochert and Steenhof 2013). Kochert et al. (1999) suggested that the carrying capacity for golden eagles in the area has declined due to a drop in jackrabbit numbers caused by habitat loss to the grass/fire cycle. Remaining golden eagles in the NCA may be at greater risk of mortality than prior to fires. Heath and Kochert (2016) found that, after major fires, eagles in the NCA switched from black-tailed jackrabbits to a variety of other prey, including rock pigeons, which are carriers of trichomaniasis, an often fatal disease. Forty-one percent of golden eagle nestlings in the NCA and surrounding area recently tested positive for the protozoan that causes trichomaniasis (Dudek and Heath 2015).

Preventing or interrupting loss of prey habitat to the grass/fire cycle is likely crucial to the conservation of golden eagles in the western U.S. (USFWS 2016). Conservation of jackrabbits and other prey is largely concordant with existing strategies for preserving or restoring habitat for imperiled wildlife species, such as greater sage-grouse (*Centrocercus urophasianus*) and Brewer's sparrows (*Spizella breweri*) (e.g., GBBO 2010; RISCT 2012; BLM 2015). However, it is possible that, at finer scales, management prescriptions to benefit these species differ from those that are optimal for jackrabbits and other golden eagle prey.

Juniper and Pinyon

Due to fire suppression, overgrazing by livestock, climate change, and other factors, juniper (*Juniperus* spp.) and pinyon (*Pinus* spp.) woodlands are increasing in extent and density across large areas of the West (Miller et al. 2000, 2005; Miller and Tausch 2001). As conifer woodlands form dense canopies, cover of shrubs, forbs, and grasses can be dramatically reduced and jackrabbits are likely impacted through loss of forage (Miller 2001; Miller et al. 2000, 2005). When woodlands become dense they are also at risk of severe fires that can facilitate invasion by cheatgrass or other exotic annual grasses that replace native habitats (Miller and Tausch 2001). Management actions for addressing conifer encroachment in native shrublands and grasslands are described elsewhere (e.g., Miller et al. 2005) and are part of existing conservation strategies for greater sage-grouse and other protected shrubland and grassland species (e.g., GBBO 2010; RISCT 2012; FIAT 2014; BLM 2015).

Mesquite

Millions of acres of desert grassland have experienced encroachment by woody plants since Euro-American settlement, particularly mesquite (Van Auken 2000). Encroachment by mesquite in desert grasslands has potentially benefited black-tailed jackrabbits. Mesquite is a major component of black-tailed jackrabbit diets in the Southwest and can provide valuable cover from heat and predators (Vorhies and Taylor 1933; Germano et al. 1983; Daniel et al. 1993a; Brown and Krausman 2003; Desmond 2004). Where management for abundant black-tailed jackrabbits is a priority, removal of mesquite (e.g., to improve rangelands for livestock) should be patchy, rather than complete. In southern Arizona, Germano et al. (1983) found significantly more black-tailed jackrabbits in undisturbed and partially cleared mesquite than in completely cleared ranges.

Climate Change

The Service (USFWS 2016:154) stated that climate change has a "strong potential to affect the carrying capacity of the landscape for eagles by impacting the abundance and distribution of prey populations." Climate change is projected to cause tremendous loss of sagebrush, compounding widespread losses that have already occurred due to conifer encroachment, invasion by exotic annual grasses, and altered fire regimes (Wagner 1999; Neilson et al. 2005). If the effects of shrub loss in the NCA are an indication, these changes could lead to large-scale habitat loss for jackrabbits and negative impacts on golden eagle populations (see Fire and Invasive Plants). Climate change may also cause complex changes in the range, composition, and ecological functioning of Southwest deserts (Brown et al. 1997; Weiss and Overpeck 2005). Rapid shifts in the locations and sizes of deserts could negatively impact jackrabbits due to their relatively limited dispersal capabilities (Schloss et al. 2012).

Information Gaps

- A substantial body of research exists concerning black-tailed jackrabbits; particularly in regard to their diets, habitat associations, population fluctuations, incidence of parasites and diseases, and relationships with predators (Flinders and Chapman 2003; Simes *et al.* 2015; this document). However, many of the studies are from the early-to-mid 20th Century and it is possible that the species' ecology has changed somewhat since then. For example, jackrabbits may currently exhibit smaller or less cyclic population fluctuations than in the past; have different geographic ranges than they did historically; or respond differently to modern livestock grazing practices than to past overgrazing (Flinders and Chapman 2003; Simes et al. 2015).

- Far less is known about the ecology and management of white-tailed jackrabbits than of black-tailed jackrabbits. In light of the white-tailed jackrabbit's importance to golden eagles and apparent rangewide decline (see Population Status), additional research is needed on the species' habitat associations, diets, and responses to habitat changes.

- Consumption of jackrabbits killed by poison or lead ammunition could be hazardous for golden eagles (see Influences on Abundance). Further research is needed to determine if alternatives to lethal control measures can be used in areas where jackrabbits are considered agricultural or rangeland pests.

- In contrast with some other mitigation measures, such as retrofitting power poles, there are currently no quantitative standards for using prey enhancement to mitigate take of golden eagles. A before-after-control-impact (BACI) study design could be used to assess the effects of habitat enhancement protocols for jackrabbits and other prey.

- Information is needed concerning the direct effects of contemporary livestock grazing on jackrabbits in shrub-steppe. More information is also needed about the ecology and population status of jackrabbits in shrub-steppe ecosystems that have been substantially altered by expansion of exotic annual grasses or encroachment by conifers. Loss or fragmentation of habitat to the grass/fire cycle is of particular concern for jackrabbits and golden eagles in shrub-steppe (see Management Considerations). The grass/fire cycle is becoming a major conservation issue in Southwest deserts as well and could likewise affect jackrabbits and golden eagles in those areas (Brooks and Pyke 2001).

- At broad scales, appropriate methods for conserving jackrabbit habitat in arid and semi-arid shrublands and grasslands are similar to those already in use for preventing or reversing large-scale habitat loss for greater sage-grouse and other protected species. However, rigorous studies are needed to determine how specific management prescriptions for restoring habitat for protected species affect jackrabbits and other prey for golden eagles.

- The effects of climate change on jackrabbits may be largely tied to broader effects on vegetation and fire patterns. Nonetheless, some aspects of jackrabbit biology merit further research in relation to climate change. For example, the effects of precipitation on jackrabbit population fluctuations are unclear and have only been studied in one region.

- Jackrabbits have traditionally been studied and managed as agricultural or rangeland pests. However, their importance to golden eagles, other predators, and ecosystem functions, as well as evidence of declining populations or habitats, indicate that they merit additional research and inclusion in conservation planning. Furthermore, the threats facing jackrabbits in many shrubland and grassland ecosystems also impact other species of conservation concern (e.g. greater sage-grouse), suggesting that jackrabbit management can be linked to existing conservation plans for imperiled landscapes and protected wildlife species.

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Appendix 1: Conservation Status of Jackrabbits in the Western United States

Conservation Status of Black-Tailed Jackrabbits in the Western United States

Location	NatureServe Status	State Wildlife Action Plan/ Conservation Strategy	State Hunting (season; limit)
Global	Secure	N/A	N/A
United States	Secure	N/A	N/A
Arizona	Secure	No mention	Open all year; no limit
California	Unranked	Focal species	Open all year; no limit
Colorado	Secure	No mention	Oct 1–end of Feb; 10/day
Idaho	Secure	No mention	Open all year; no limit
Kansas	Secure	No mention	Open all year; 10/day
Montana	Imperiled	Lacks a baseline survey. Target for survey and inventory.	Open all year; no limit
Nebraska	Secure	Tier II (at risk)	Sep 1–end of Feb; 4/day
Nevada	Secure	No mention	Open all year; no limit
New Mexico	Secure	No mention	Open all year; no limit
North Dakota	No status provided	No mention	Open all year; no limit
Oklahoma	Secure	Does not meet greatest conservation need criteria	Oct 1–Mar 15; 3/day
Oregon	Apparently Secure	No mention	Open all year; no limit
South Dakota	Apparently Secure	No mention	Open all year; no limit
Texas	Secure	No mention	Open all year; no limit
Utah	Secure	No mention	Open all year; no limit
Washington	Imperiled/Vulnerable	Species of Greatest Conservation Need	Closed statewide and year-round
Wyoming	Secure	No mention	Open all year; no limit

Conservation Status of White-Tailed Jackrabbits in the Western United States

Location	NatureServe Status	State Wildlife Action Plan/ Conservation Strategy	State Hunting (season; limit)
Global	Secure	N/A	N/A
United States	Secure	N/A	N/A
Arizona	No status provided (outside range)	N/A	N/A
California	Unranked	Focal species	Open all year; no limit
Colorado	Apparently Secure	Tier 2 (remains important in light of population trends or habitat conditions)	Oct 1–end of Feb; 10/day
Idaho	Secure	No mention	Open all year; no limit
Kansas	Presumed Extinct	No mention	Open all year; 10/day
Montana	Apparently Secure	No mention	Open all year; no limit
Nebraska	Apparently Secure	Tier II (at risk)	Sep 1–end of Feb; 4/day
Nevada	Secure	No mention (small game status book notes Concern due to habitat loss)	2nd Sat in Oct–Feb 28; 10/day
New Mexico	Imperiled	No mention	Open all year; no limit
North Dakota	Unranked	No mention	Open all year; no limit
Oklahoma	No status provided (outside range)	N/A	N/A
Oregon	Apparently Secure?	Sensitive species	Closed statewide and year-round
South Dakota	Apparently Secure	No mention	Open all year; no limit
Texas	No status provided (outside range)	N/A	N/A
Utah	Vulnerable/Apparently Secure	No mention	Open all year; no limit
Washington	Imperiled/Vulnerable	Species of Greatest Conservation Need	Closed statewide and year-round
Wyoming	Apparently Secure	No mention	Open all year; no limit