Marmots

Biology of Yellow-Bellied Marmots (*Marmota flaviventris*) as Prey of Golden Eagles (*Aquila chrysaetos*) in the Western United States

Marmots

Biology of Yellow-Bellied Marmots (*Marmota flaviventris*) as Prey of Golden Eagles (*Aquila chrysaetos*) in the Western United States

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

Date: November 13, 2017

Disclaimer

The reports in this series have been prepared by the U.S. Fish and Wildlife Service (Service) Western Golden Eagle Team (WGET) for the purpose of proactively addressing energy-related conservation needs of golden eagles in Regions 1, 2, 6, and 8. The team was composed of Service personnel, sometimes assisted by contractors or outside cooperators. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

Suggested Citation

Hansen, D. L., D. Leal, and G. Bedrosian. 2017. Biology of yellow-bellied marmots (*Marmota flaviventris*) as prey of golden eagles (*Aquila chrysaetos*) in the western United States. Unpublished report prepared by the Western Golden Eagle Team, U.S. Fish and Wildlife Service. Available online at: *https://ecos.fws.gov/ServCat/Reference/Profile/87152*

Acknowledgments

This report was authored by Dan L. Hansen, David Leal, and Geoffrey Bedrosian. The authors are grateful to the following reviewers (in alphabetical order): Colleen Lenihan, Katie Powell, Dirk Van Vuren, James Watson, and Hillary White.

Summary

Yellow-bellied marmots (*Marmota flaviventris;* hereafter, "marmots") are large burrowing squirrels (order Rodentia, family Sciuridae). They are widely documented as prey of breeding golden eagles (*Aquila chrysaetos*) in the western United States (U.S.). Marmots may be optimal sized prey for golden eagles and can be an abundant and stable food source. However, their distribution is limited by the availability of suitable rocky habitat and they only occur at high frequencies in the diets of golden eagles in particular areas, such as at high elevations. Marmots hibernate and are unavailable as prey during most or all of the golden eagle's nonbreeding season, depending on the region and elevation.

This account only describes yellow-bellied marmots. Other marmot species have limited distributions in the western U.S. and are unlikely to be important prey for golden eagles at broad spatial scales. A potential exception is the hoary marmot (*M. caligata*), which is an important prey species for golden eagles in Alaska (McIntyre and Adams 1999). Within the conterminous western U.S., hoary marmots could be important prey for golden eagles at high elevations in the northern Rocky Mountains (Idaho and Montana) and Washington Cascades. However, we are unaware of any information concerning golden eagles and their diets in those areas. See Braun et al. (2011) for more information about hoary marmots.

Yellow-bellied marmots typically live on vegetated talus slopes or in well-drained rock outcrops in meadows. Other suitable habitat occurs within a variety of rocky areas. Rocky burrows may be a limiting resource for marmots and appear to strongly influence the species' distribution, population density, and social structure. Marmots spend the majority of their lives in burrows and use them as nurseries and for hibernation, resting, and protection from weather, predators, and other marmots. Marmots also occur in some urban and agricultural settings, provided suitable rocky cover is available.

The availability of suitable forage is important for marmots. Foraging is typically limited to short distances from the home burrow, generally in low-growing vegetation. Marmots primarily eat forbs and grasses. Grasses are more consistently available than forbs; however, marmots prefer forbs, which have a higher nutrient and moisture content. Marmots eat some agricultural crops but their activity in agricultural settings is likely generally limited to the edges of fields, near rocky cover.

Numbers of adult marmots living in colonial burrows are generally stable, while marmots in satellite (isolated) burrows experience larger fluctuations in density and reproduce at lower rates. Changes in marmot densities are primarily due to annual differences in production of young. However, dispersal and mortality also affect population numbers, particularly for male young and yearlings.

Populations of marmots are regulated to a large degree by their social structure, which strongly influences dispersal, recruitment, and reproduction. Environmental factors can also greatly affect reproduction and survival of marmots. Predation and weather appear to have particularly strong affects on the behavior and demography of marmots. Disease outbreaks may cause local die-offs for some marmot populations.

Yellow-bellied marmots are not recognized as a species of conservation concern. Human activities appear to have mixed effects on the species. Urban and agricultural development may positively or negatively influence them, depending on how rocky cover is affected. Marmots are considered agricultural pests in some areas and are sometimes controlled with lethal measures. Golden eagles could be at risk of secondary poisoning in areas where marmots are controlled with rodenticides or shooting with lead ammunition. Climate change has apparently had positive short-term effects on marmots by increasing the length of the growing season and marmots' ability to obtain fat reserves for hibernation and reproduction. However, researchers have expressed concern that climate change could negatively impact the species in the long term. Furthermore, climate change, along with fire suppression, could be reducing the quality or availability of higher-elevation meadow habitats for marmots.

Much of what is currently known about marmots is based on research at higher elevations in Colorado. Studies are needed to describe the natural history, behavior, and demography of the species elsewhere, particularly in more arid, lower-elevation areas. Other research topics relevant to understanding and managing marmots as prey for golden eagles include the long-term demographic effects of climate change; whether and how prescribed fire and tree removal should be used to maintain or enhance higher-elevation meadow habitats; and effects of urban and agricultural development on the species.

Table of Contents

Importance to Golden Eagles

Occurrence in Golden Eagle Diets

Bedrosian et al. (2017) synthesized data concerning the of breeding season diets of golden eagles within 45 study locations in the conterminous western United States (U.S.), southern Canada, and northern Mexico. Based on the percentage of identified prey individuals, yellow-bellied marmots (*Marmota flaviventris;* hereafter, "marmots") were among the top three breeding season prey taxa for golden eagles in 9 (20%) of the reviewed studies (Hickman 1968; McGahan 1968; Reynolds 1969; Knight and Erickson 1978; Bloom and Hawks 1982; Thompson et al. 1982; Marr and Knight 1983; Keller 2015; Watson and Davies 2015; see Figure 1). In higher-elevation areas of Utah and Wyoming, marmots were among the top three prey taxa in 1 of 3 studies (Keller 2015), and occurred at lower frequencies in golden eagle diets in both of the other studies (Arnell 1971; Schmalzried 1976). Marmots are also prey for golden eagles in an ecologically similar high-elevation area of west-central Colorado (Armitage and Downhower 1974; Van Vuren 2001), though their frequency in eagle diets in that area is unknown. Marmots were in the top three prey in 2 of 4 diet studies in southeastern Montana and northern Wyoming (McGahan 1968; Reynolds 1969) and were reported as less frequent prey in a third study (R. Crandall and C. Preston, unpubl. data). Marmots were in the top three prey in 6 of 25 (24%) golden eagle diet studies in intermountain basin shrub-steppe, which extends from northern New Mexico to eastern Washington (Hickman 1968; Knight and Erickson 1978; Bloom and Hawks 1982; Thompson et al. 1982; Marr and Knight 1983; Watson and Davies 2015). Three of the studies in which marmots were top prey were located in the Columbia Plateau of eastern Washington. Marmots were also reported as less frequent prey (i.e., not in the top three prey) in multiple studies in the Idaho portion of the Cold Deserts ecoregion (Beecham 1970; Kochert 1972; Marzluff et al. 1997; Steenhof and Kochert, unpubl. data); as well as an ecologically similar area near the California-Oregon border (B. Woodbridge, unpubl. data).

Few studies have investigated golden eagle diets during the nonbreeding season and none of them reported marmots as prey (Woodgerd 1952; Arnold 1954; Edwards 1969; Hayden 1984; Marzluff et al. 1997). Marmots hibernate and are not available as prey during most or all of the golden eagle's nonbreeding season. Marmots typically hibernate from August or September until late February–May, with later emergence times at higher elevations (reviewed in Frase and Hoffmann 1980). Additionally, marmots in arid, lower-elevation areas estivate, which is prolonged torpor or dormancy during hot or dry periods (reviewed in Frase and Hoffman 1980). Marmots in arid, lower-elevation areas may begin to estivate as early as June, possibly because of reduced availability of green vegetation (reviewed in Frase and Hoffmann 1980).

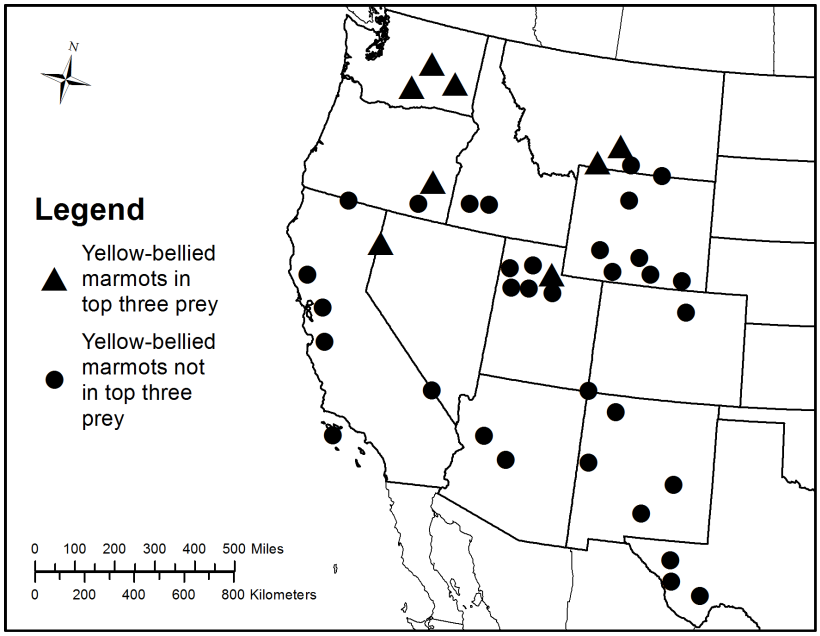

Figure 1: Locations of studies in which yellow-bellied marmots were in the top three breeding season prey taxa for golden eagles based on percentage of identified prey individuals (see Bedrosian et al. 2017).

Influence on Golden Eagles

Whether marmots influence golden eagle individuals or populations is unknown. Marmots may be particularly important prey for golden eagles at higher elevations and in other areas where more widely important prey are unavailable (i.e., leporids [Family Leporidae] and squirrels [Family Sciuridae]: see Bedrosian et al. 2017). In contrast with leporids (see jackrabbit account and cottontails account), marmots do not exhibit dramatic multi-annual population fluctuations (see Population Fluctuations) and thus, may have less obvious effects on golden eagle populations. Furthermore, they are unavailable as prey for most or all of the golden eagle's nonbreeding season and may therefore have little influence on eagles' overwinter survival and ability to attain breeding condition.

Prey Species Information

Physical Description

Marmots are short-legged, have a 'squat' stature, and have a relatively short, bushy tail (Armitage et al. 1976). Their pelage consists of a thick, woolly underfur covered by coarse guard hairs. Their overall coloration is yellowish-brown, frosted with buffy-white on the back and sides, and they have a prominent white muzzle and a blackish mask (Frase and Hoffman 1980). Yellow-bellied marmots are one of the largest sciurids in western North America. Their total length is 18.5 to 27.6 inches (470–700 millimeters) (Frase and Hoffman 1980). Lean (post-hibernation) weights of marmots averaged 8.6 pounds (lbs) (3.9

kilograms [kg]) for adult males and 6.2 lbs (2.8 kg) for adult females (Armitage et al. 1976). Males are typically longer and heavier than females (Frase and Hoffman 1980). Marmots in drier, lower-elevation areas are generally smaller than those at higher elevations (Armitage 2017). Marmots at both high and low elevations are considered optimal-sized prey for golden eagles (Watson 2010; Schweiger et al. 2015).

Ecological Roles

Marmots may be thought of as "ecosystem engineers" (Jones et al. 1994). By digging burrows, they create cool, dark habitat for other animals that burrow or dwell underground, such as insects, snakes, or amphibians (Davidson et al. 2012). Excavation of burrows aerates the soil, brings nutrients to the surface, and creates mounds of soil that are used by other organisms (Davidson et al. 2012). Marmots could also influence vegetation patterns; for example, through selective herbivory or seed predation (see Diet). Additionally, they are prey for golden eagles and other predators, such as coyotes (*Canis latrans*) and badgers (*Taxidea taxus*) (see Predators). Davidson et al. (2012:477) stated that "by grouping together socially, they (marmots and other social, burrowing, herbivorous mammals)...create distinctive habitat patches that serve as areas of concentrated prey for many predators."

Distribution

The yellow-bellied marmot's range includes much of the conterminous western U.S., from western Montana south to northern New Mexico and east into the Cascade Mountains and Sierra Nevada (Frase and Hoffman 1980; Figure 2). In the northern portion of its range, the species typically occurs only in warm, dry habitats at low to mid-elevations; southward, it occurs from semi-desert up to the alpine zone; and in the southern and western part of its range, it is generally limited to higher elevations (ca. 6,560–11,800 feet [ca. 2,000–3,600 meters]) (Frase and Hoffman 1980; Floyd et al. 2005). Frase and Hoffman (1980:3) noted that "because of its absence from valleys, southern populations are in many cases isolated from one another, on a series of montane 'islands'." The sporadic distribution of marmots across eastern Oregon was attributed to the absence of suitable rocky substrate with nearby succulent vegetation (Verts and Carraway 1998); a pattern which likely applies throughout the species' range (Hoffman 1974; see Habitat Associations).

Habitat Associations

Marmots typically live on vegetated talus slopes or in well-drained rock outcrops in meadows (reviewed in Frase and Hoffman 1980). Other suitable habitat occurs within a wide variety of rocky areas, such as lava fields, rimrock, cliffs, and canyon walls, and is located within many vegetation types (Bailey 1936). Marmots use rocks as support for burrows and as observation and sunning posts (Travis and Armitage 1972; Svendsen 1976).

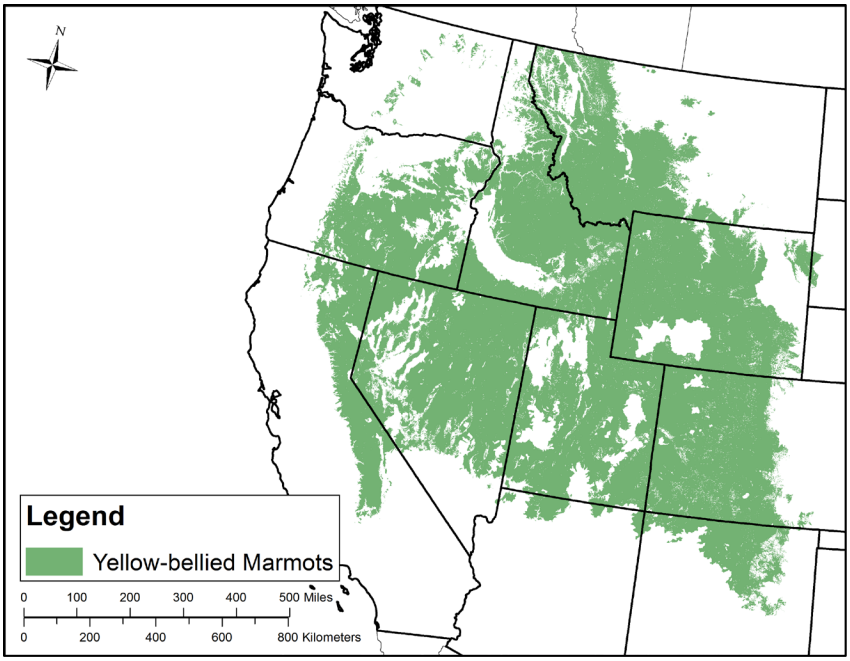

Figure 2: Modeled distribution of yellow-bellied marmots (USGS-GAP 2013).

Rocky burrows may be a limiting resource for marmots and appear to influence the species' distribution, population density, and social structure (Andersen et al. 1976; Johns and Armitage 1979; Thompson 1979). Marmots spend up to 80% of their lives in burrows (Svendsen 1976; Armitage 2017). Burrows provide stable temperature environments important for hibernation and thermoregulation (Kilgore 1972 cited in Frase and Hoffman 1980). They are also used as nurseries and for protection from weather, predators, and other marmots (Svendsen 1976; Van Vuren 2001; Blumstein et al. 2006).

The availability of suitable forage (see Diet) near rocky cover is important for marmots. Although they are capable of longer seasonal or dispersal movements (e.g., Thompson 1979), marmots are central place foragers that typically feed at short distances (≤65 feet [20 meters]) from their home burrow (Johns and Armitage 1979). They usually forage in short vegetation (Johns and Armitage 1979), which could be related to predator detection (Carey 1985; Van Vuren 2001), as well as a dietary preference for forbs over taller-growing graminoids (see Diet).

Marmots can occur in urban, exurban, and agricultural settings when suitable rocky cover is available (Verts and Carraway 1998). In most agricultural operations, rocks are removed from fields for ease of tilling, harvesting, and watering, and may be piled nearby, incidentally creating habitat for marmots. Marmots can be particularly abundant in rock piles adjacent to alfalfa (*Medicago sativa*) fields (D. Van Vuren, J. Watson, and B. Woodbridge, pers. comm.). Foraging by marmots in agricultural settings is likely generally limited to the edges of fields, close to rocky burrows (Johns and Armitage 1979). Marmots also use human-created rock outcrops on golf courses or rock-reinforced slopes along railroad tracks, as well as large piles of wood (D. Van Vuren, J. Watson, and B. Woodbridge, pers. comm.).

Diet

Marmots primarily eat forbs and grasses (reviewed in Frase and Hoffman 1980). They also eat large numbers of seeds during late summer (Bailey 1936; Frase unpubl. data cited in Frase and Hoffman 1980), perhaps due to their relatively high moisture and nutritive content (White 2011). Some marmots may also eat insects, such as caterpillars (Bailey 1936), and small amounts of lichens and mushrooms (Stallman and Holmes 2002). Marmots consume agricultural crops, such as grains, alfalfa, clover (*Trifolium*), and hay grasses, when available (Thompson 1979; Marsh 1984; Verts and Carraway 1998).

In west-central Colorado, Armitage (2003) observed marmots standing on their hind legs to eat the flowers of tall forbs (*Lupinus, Aquilegia, Delphinium*) and the seed heads of grasses. Marmots may only eat the flowers of those particular forbs because of the presence of alkaloids in other parts of those plants (Armitage 1979). Marmots in the area fed on spring beauty (*Claytonia*) during early spring, when few other plants were available. They extensively foraged on fruits of gooseberries (*Ribes*) and elderberry (*Sambucus*) during late summer (Armitage 2003).

Marmots in the White Mountains of eastern California likewise ate forbs and grasses (Carey 1985; Stallman and Holmes 2002). Forbs were especially prevalent in the diet during late spring through summer, while graminoids composed more of the diet during early spring. Clover (*T. andersonii*) was the most common identifiable plant in marmot diets. Carey (1985) reported that its relative abundance in marmot diets was 8% in spring, 45% in early summer, and 56% in midsummer. Stallman and Holmes (2002) found that it constituted 61% of the diet during spring through summer. Other forbs identified in marmot diets included mustards (*Draba* and *Arabis*) and phloxes (*Phlox* and *Leptodactylon*) (Stallman and Holmes 2002). Stallman and Holmes (2002) found a variety of graminoids in marmot feces, including sedges (*Carex*), bluegrasses (*Poa*), and junegrass (*Koeleria macrantha*).

Marmots are generalist herbivores and the composition of their diets may depend to a large degree on the distributions and phenology of edible plants (Frase and Armitage 1989). Nonetheless, they clearly favor forbs over grasses and other more widespread and abundant plants (Carey 1985; Stallman and Holmes 2002; Armitage 2003). Marmots may prefer forbs over grasses because of their lower cellulose content and greater nutritional value; though graminoids may also be important to marmots because they are more consistently available on the landscape and throughout the active season (Carey 1985; Florant et al. 1990). Frase and Armitage (1989) stated that the dietary choices of marmots are likely unaffected by water content except during prolonged droughts. However, researchers in the arid White Mountains suggested that higher water content is one of the reasons marmots selectively forage on forbs rather than graminoids (Stallman and Holmes 2002).

Population Fluctuations and Densities

Numbers of marmots fluctuated fourfold during a 40-year study in west-central Colorado (Oli and Armitage 2004). Density (all age classes, both sexes) ranged from 1.4 to 3.4 marmots per acre (3.5–8.5 per hectare) and was typically highest in August after each year's young were weaned (Johns and Armitage 1979). Annual mortality was high for all

age classes (average annual weighted mortality = 42% for females and 53% for males) (Schwartz et al. 1998). However, changes in densities of marmots primarily result from annual differences in production of young (Armitage 1991). Dispersal is also responsible for a large proportion of annual losses of study animals (Johns and Armitage 1979). Numbers of male yearlings substantially decline each active season because of dispersal and mortality (Armitage and Downhower 1974; Johns and Armitage 1979).

Marmots live in either colonial or satellite (isolated) burrows (reviewed in Frase and Hoffman 1980; also see Svendsen 1974). Colonies typically have multiple burrows with one adult male and a harem of one or more females and their young (Andersen et al. 1976). Satellite areas generally have a limited number of burrows; typically have one marmot, a pair, or a female and her young; and are occupied by transient or socially subordinate individuals (reviewed in Frase and Hoffman 1980). Numbers of adults in colonies are relatively stable, whereas satellites exhibit greater fluctuations and lower reproductive rates than colonial populations (Armitage and Downhower 1974; Armitage 1991).

Influences on Abundance

Populations of marmots are regulated to a large degree by their social structure (female kin groups; reproductive suppression; male territoriality), which strongly influences dispersal, recruitment, and reproduction (Armitage 1991; Oli and Armitage 2004). However, as reviewed below, environmental factors can also greatly affect reproduction and survival of marmots; either directly (e.g., predation) or indirectly (e.g., weather's effect on the length of the active season).

Whether information based on long-term research of high-elevation marmots in Colorado applies to populations in more arid or lower-elevation areas is unclear. Marmots generally occur in relatively harsh environments with short growing seasons (see Distribution). Thus, marmots at lower elevations may be similarly affected by environmental factors that influence their ability to attain sufficient fat reserves for hibernation and reproduction.

Parasites and Diseases

Marmots are hosts to an array of parasites (reviewed in Frase and Hoffman 1980). In Colorado, yearlings with slower growth rates, individuals that died overwinter, and adult females that failed to reproduce had higher loads of fleas (*Oropsylla stanfordi*) than did other individuals (Van Vuren 1996). Van Vuren (1996) suggested that high ectoparasite loads could impact the fitness of marmots in multiple ways. For example, individuals with high ectoparasite loads could fail to attain the physical condition necessary to survive hibernation or reproduce, or could be affected by diseases transmitted by ectoparasites. Research on alpine marmots (*M. marmota*) found similar associations between high ectoparasite loads and increased overwinter mortality and reduced reproduction (Arnold and Lichtenstein 1993).

Yellow-bellied marmots are also hosts to a variety of diseases, some of which may be directly or indirectly transmitted to humans; for example, Rocky Mountain Spotted Fever (*Rickettsia rickettsii*; Cockrum 1997) and sylvatic plague (*Yersinia pestis*; Nelson 1980).

Nelson (1980) stated that marmots appear to be highly susceptible to sylvatic plague and undergo intense local die-offs because of it.

Weather

Weather can strongly affect the behavior, fitness, and demography of marmots. For example, survival of young marmots was positively associated both with later onset and earlier termination of winter; most likely because of a longer growing season and more opportunities to obtain sufficient fat reserves for hibernation (Armitage and Downhower 1974; Schwartz and Armitage 2005). Later termination of winter can negatively affect reproduction, perhaps by causing females to deplete fat stores and lose reproductive condition (Van Vuren and Armitage 1991; Schwartz and Armitage 2005). Weather during the spring and summer can also influence reproduction and survival of marmots (Schwartz and Armitage 2005). For example, survival of young marmots was negatively associated with low summer precipitation (Schwartz and Armitage 2005), whereas exposure during summer storms killed some young (Armitage and Downhower 1974). See Armitage and Downhower (1974), Andersen et al. (1976), Van Vuren and Armitage (1991), and Schwartz and Armitage (2005) for more information about how weather affects marmots.

Climate Change

Marmots at high elevations in Colorado are emerging from hibernation significantly earlier than in previous decades, and are also weaning their young earlier (Inouye et al. 2000; Ozgul et al. 2010). These changes appear to be a response to increased mean air temperatures in April caused by anthropogenic climate change (Inouye et al. 2000). Earlier emergence from hibernation and earlier weaning of young has led to a longer growing season for marmots in the area, which has contributed to larger body masses before hibernation, higher rates of survival and reproduction, and a rapid increase in population size (Ozgul et al. 2010).

While the effects of recent climate change on the species appear to have been positive thus far, the long-term effects could be negative for some populations (Armitage 2013, 2017). The long-term effects of climate change on marmots may largely depend on changes to the timing of snowmelt during winter/spring and effects on temperature and precipitation patterns during summer (Inouye et al. 2000; Ozgul et al. 2010; Armitage 2013, 2017). Earlier emergence without earlier snowmelt could increase the risk of starvation or reduce reproduction by delaying marmots' access to food and forcing them to continue relying on fat reserves after hibernation (Inouye et al. 2000; Armitage 2013). Prolonged snow cover during one winter caused mortality of about 50% of adults and 80% of young in a population in Colorado and reduced reproduction the following year (Armitage 2013). Increased frequency of long, dry summers, which are forecasted to occur in some areas under plausible climate change scenarios, could decrease growth rates and negatively affect survival and reproduction of marmots (Ozgul et al. 2010; Armitage 2013, 2017). As described below (see Management Considerations), climate change could also negatively affect higher-elevation populations of marmots through loss of meadow habitats.

Predators

Predation on yellow-bellied marmots is rarely directly observed and was previously thought to occur infrequently (Frase and Hoffman 1980). However, it is now known to be a primary source of mortality for the species (Thompson 1979; Van Vuren 2001). Van Vuren (2001) noted that none of the predator-caused mortalities documented in his 12-year radio-telemetry study in west-central Colorado were directly observed. During another long-term (20-year) study in the same area, only 2 predation events were observed during more than 5,000 hours of behavioral observations of marmots (Armitage 1982). Although predation on marmots was cryptic, Van Vuren (2001) found that it was the source of 93 of 97 (96%) mortalities recorded during his study in Colorado. Coyotes were responsible for nearly half (45%) of the mortalities, followed by badgers (10%), American martens (*Martes americana*; 7%), black bears (*Ursus americanus*; 7%), raptors (6%), and unidentified predators (18%; likely coyotes and other mammalian predators based on the states of the remains found). Van Vuren (2001) thought that golden eagles were likely the primary raptor that preyed on marmots in his study, because of their ability to carry large prey and because golden eagle feathers were found at two sites where marmot radio transmitters were found. Thompson (1979) directly observed predation of 10 marmots by coyotes and badgers during his 4-year study in central Oregon, and stated that there was "convincing circumstantial evidence" that as many as 50 or more marmots in his study were killed by predators. He did not observe predation of marmots by raptors. However, Bailey (1936) stated that "many jaws and bones" of juvenile marmots were found under nests of Swainson's hawks (*Buteo swainsoni*), red-tailed hawks (*B. jamaicensis*) and great horned owls (*Bubo virginianus*) in Oregon. Other documented predators of marmots include gray wolves (*Canis lupus*) and bobcats (*Lynx rufus*) (Frase and Hoffman 1980).

Control Measures

Although marmots may generally be limited to the edges of cultivated fields because of their limited foraging range and close association with rocky cover (see Habitat Associations), they are considered agricultural pests in some areas because of their consumption and trampling of crops (Marsh 1984; USDA 2003; see Diet). They may also be considered pests because of their burrowing habits, which can damage irrigation structures, levees, or other human structures (USDA 2003). Marmots may therefore be subject to control efforts, such as shooting or poisoning (USDA 2003; VPCRAC 2014). Indeed, marmots are primary targets for "varmint" hunters in some western states (J. Watson, pers. comm.). Consumption of shot or poisoned marmots could be a source of secondary lead or rodenticide poisoning for golden eagles (Herring et al. 2017). We are unaware of any published information about the effects of control measures on marmot populations. It is possible that some marmots become partially nocturnal in response to shooting by humans, and thus, less available as prey for the diurnal golden eagle (Dalquest 1948).

Habitat Loss or Modification

Marmots are closely associated with rocky habitats (see Habitat Associations), which are often located in areas unsuitable for agricultural or urban development, such as alpine areas, canyons, and lava fields (see Distribution). However, in the northern part of their

range, marmots inhabit a broader range of habitats at lower elevations and may therefore experience some habitat modification caused by urbanization or agriculture.

Rocks are typically removed from agricultural fields for ease of cultivation and to reduce damage to equipment. Rocks removed from fields are sometimes piled nearby, inadvertently creating habitat for marmots. In parts of eastern Washington, golden eagles may have shifted their diets from leporids to marmots because of conversion of shrub-steppe to agriculture near rocky canyons used by marmots (Dobler et al. 1996; Watson and Davies 2015).

Marmots have shown an ability to adapt to urban development where rocky cover remains. They can be readily seen around roads and housing developments in some towns, such as Bend, Oregon and Spokane, Washington. In Bend, an abundance of basalt boulders and rock outcrops have been incorporated into landscaping (e.g., in parks and golf courses), which can provide habitat for marmots. Eagles nesting within or nearby these communities may prey on marmots.

Population Status

Yellow-bellied marmots are globally ranked as a species of "least concern" by the International Union for Conservation of Nature (IUCN 2017); and globally and nationally "secure" by NatureServe (2017). NatureServe (2017) ranks them as "secure" or "apparently secure" in most states (Appendix 1). They are ranked as "imperiled" in New Mexico, which is at the southern extreme of their range and where they have a very limited distribution (see Distribution). NatureServe (2017) did not provide a ranking for Arizona, which is also at the southern edge of the species' range. Yellow-bellied marmots are not mentioned or are not recognized as being in need of conservation measures in any western State Wildlife Action Plans or Conservation Strategies (Appendix 1). Marmots are either unmentioned or unprotected (no season or bag limit) in most western states' hunting regulations (Appendix 1). Greater conservation concern exists for hoary marmots (M. caligata) and Olympic marmots (M. olympus), which are mentioned in some states' Wildlife Action Plans and hunting regulations (Appendix 1). The only long-term demographic data available for yellow-bellied marmots is from research of a high-elevation population in west-central Colorado. The projected growth rate for that population, based on 40 years of research, was 0.97 ± 0.03, indicating a stable or slightly declining population (Oli and Armitage 2004).

Management Considerations

Yellow-bellied marmots are not recognized as a species of conservation concern at large spatial scales (see Population Status and Appendix 1). Despite the yellow-bellied marmot's low conservation ranking, however, human activities may be negatively affecting some colonies or populations. Conversely, marmots often use habitats created by humans, suggesting that intentional creation of habitat could be used to increase availability of marmots as prey for golden eagles; for example, as a conservation mitigation measure.

Habitat Management

As described above, some lower-elevation marmot populations may experience habitat loss or degradation caused by urbanization or agricultural conversion, while others may benefit from incidental creation of rocky habitat or increased local food supply in the form of cultivated crops or landscaping. Retaining and piling rocks during agricultural operations or incorporating them into urban or exurban landscaping (e.g., on golf courses) could benefit marmots and thereby maintain or increase their availability as prey for golden eagles. Marmots can reach particularly high densities in rock piles adjacent to alfalfa fields or pastures (D. Van Vuren, J. Watson, and B. Woodbridge, pers. comm.). Marmots also use large wood piles as habitat. For example, marmots have been observed using large mounds of stumps and dirt created during juniper (*Juniperus* spp.) clearing projects (B. Woodbridge, pers. comm.), and a population is known to exist within a stack of tens of thousands of discarded railroad ties (D. Van Vuren, pers. comm.).

We are unaware of published information regarding how to intentionally construct habitat for marmots, beyond simply piling rocks or wood. However, Svendsen (1974, 1976) described some characteristics of rocky burrows used by marmots at higher elevations in Colorado. For instance, marmots rarely used rock outcrops in forests, preferring those in open environments containing herbaceous vegetation (Svendsen 1976). Approximately 75% of burrows were located on slopes between 15° and 40° (mean = 27°) (Svendsen 1976). Burrows were also more frequently found on southwesterly slopes than expected by chance, presumably because marmots use rocks near their burrows for sunning. Additionally, burrows were often excavated in soils sufficiently rocky to prevent badgers or other digging predators from widening and entering them, but in which rocks were not so deep or tightly packed that marmots were unable to excavate below them (Svendsen 1976; Andersen and Johns 1977).

Control Measures

Marmots are considered pests in some areas because of their consumption of crops and burrowing under human structures. Measures used to control marmots may negatively affect golden eagles. For example, eagles may be harmed if they consume marmots that have been poisoned by anticoagulant rodenticides or shot with lead ammunition (Herring et al. 2017). Furthermore, control measures may reduce availability of marmots as prey. Minimizing control measures could be an important step for maintaining healthy populations of marmots as prey for golden eagles (J. Watson, pers. comm.).

Climate Change

Some higher-elevation marmot populations may be at risk because of habitat loss (Armitage 2013; WDFW 2015; IDFG 2017). Warming temperatures and reduced snow packs associated with anthropogenic climate change are facilitating encroachment by trees and shrubs into some subalpine and alpine meadows and therefore, potentially reducing habitat quality or availability for some marmots (Armitage 2013; WDFW 2015). Reduced wildfire frequency due to fire suppression could also be contributing to encroachment by trees and shrubs (WDFW 2015; IDFG 2017). Rising tree lines in some higher-elevation

areas could result in habitat fragmentation and population isolation for some marmot populations, thereby increasing their risk of inbreeding and local population extinction (WDFW 2015). Removal of trees, prescribed fire, or other actions may be needed to reverse or avoid degradation or loss of montane meadow habitats for marmots (WDFW 2015).

Some marmots are emerging earlier from hibernation because of warming temperatures caused by climate change (Inouye et al. 2000; Ozgul et al. 2010). Earlier emergence, and thus, a longer active season, enables them to store more fat before hibernation and thereby contributes to greater survival and reproduction (Ozgul et al. 2010). However, marmots may also be at greater risk of starvation when they emerge while snow still covers much of their food supply (Inouye et al. 2000; Armitage 2013, 2017). Climate change could also negatively impact marmots in the long-term if summers become longer and dryer, as some modeling suggests (Armitage 2013, 2017). Continued research is needed concerning the potential effects of climate change on marmots and possible mitigation measures for conserving the species.

Information Gaps

- A tremendous body of scientific information is available concerning the natural history, behavior, and demography of yellow-bellied marmots. However, it is almost entirely based on research in a single high-elevation area in Colorado. There is little published information about the species in other parts of its range. Information is particularly needed for marmots in arid, lower-elevation areas.

- It is unknown whether yellow-bellied marmots influence golden eagle populations. The influence of marmots on golden eagles could be more difficult to detect than it is for leporids that exhibit extreme multi-annual population fluctuations (see jackrabbit account and cottontails account). However, it might be more detectable in areas where marmots are primary prey and where their availability to eagles is altered (either positively or negatively) by urban or agricultural development.

- Climate change has apparently had positive short-term effects on marmots at high-elevations in Colorado. However, climate change could have negative impacts on the species in the long term. Continued research of this topic is needed and should include studies in more arid, lower-elevation areas.

- Relatively little is known about the degree to which predation affects yellow-bellied marmot populations. Additional radio-telemetry studies are needed to further investigate this topic, particularly outside of west-central Colorado, where previous research on predation was conducted.

- Control of marmots with anticoagulant rodenticides or shooting with lead ammunition could reduce their availability as prey and cause secondary poisoning of golden eagles. Alternative methods of control should be explored where marmots are prey for golden eagles, such as use of non-lethal control measures or educating the public about using non-lead ammunition. Approaches other than control should also

be considered for conserving marmots in areas where they are considered pests, such as purchasing conservation easements on farmers' lands with substantial marmot populations or reimbursing farmers that experience crop damage by marmots.

- Research is needed to investigate how urban and agricultural development affect the distribution and abundance of marmots. Information about this topic could also illuminate potential methods for purposefully increasing availability of marmots as prey for golden eagles; for example, by creating marmot habitat as a conservation mitigation measure for golden eagles.

- Encroachment by trees and shrubs into higher-elevation meadows could be reducing habitat availability or quality for marmots and could isolate populations. Research is needed to investigate whether this is occurring for yellow-bellied marmots and, if so, how prescribed fire, tree removal, and other management activities affect habitat conditions and marmot populations.

- Wind energy development near marmot colonies could put golden eagles at risk. This could be a particular concern in the Columbia Plateau (e.g., along expansive rimrock canyons above rivers), where wind energy developments are concentrated and the marmot is one of the golden eagle's primary breeding season prey (J. Watson, pers. comm.). Empirical or modeled information about the local distribution of marmots could be of value for determining where wind turbines may put foraging eagles at risk; particularly in higher-elevation territories, where marmots are most likely to be important prey.

- More information is needed regarding the diets of golden eagles in forested montane environments, including in the northern Rockies and northern Cascades, where hoary marmots are potentially important prey. Research is also needed concerning the potential importance of Olympic and Vancouver Island marmots (*M. vancouverensis*) to golden eagles in western Washington (J. Watson, pers. comm.). This account will be updated with information about other marmot species if they are found to be important prey for golden eagles in the conterminous western U.S.

References

Andersen, D.C., K.B. Armitage, and R.S. Hoffman. 1976. Socioecology of marmots: female reproductive strategies. Ecology 57(3):552–560.

Armitage. K.B. 1979. Food selectivity by yellow-bellied marmots. Journal of Mammalogy 60(3):628–629.

Armitage, K.B. 1982. Marmots and coyotes: behavior of prey and predator. Journal of Mammalogy 63(3):503–505.

Armitage, K.B. 1991. Social and population dynamics of yellow-bellied marmots: results from long-term research. Annual Review of Ecology and Systematics 22:379–407.

Armitage, K.B. 2003. Observations on plant choice by foraging yellow-bellied marmots. Oecologia Montana 12:25–28.

Armitage, K.B. 2013. Climate change and the conservation of marmots. Natural Science 5:36–43.

Armitage, K.B. 2017. Hibernation as a major determinant of life-history traits in marmots. Journal of Mammalogy 98(2):321–333.

Armitage. K.B., D.T. Blumstein, and B.C. Woods. 2003. Energetics of hibernating yellow-bellied marmots (*Marmota flaviventris*). Comparative Biochemistry and Physiology Part A 134:101–114.

Armitage, K.B. and J.F. Downhower. 1974. Demography of yellow-bellied marmot populations. Ecology 55(6):1233–1245.

Armitage, K.B., J.F. Downhower, and G.E. Svendsen. 1976. Seasonal changes in weights of marmots. American Midland Naturalist 96(1):36–51.

Arnell, W.B. 1971. Prey utilization by nesting golden eagles (*Aquila chrysaetos*) in central Utah. M.S. thesis. Brigham Young University, Provo, Utah.

Arnold, L.W. 1954. The golden eagle and its economic status. U.S. Fish and Wildlife Circular 27. Pp. 1–35 *in* E.R. Kalmbach, R.H. Imler, and L.W. Arnold (eds.). The American eagles and their economic status. USFWS and Bureau Sport Fisheries and Wildlife. Washington, D.C.

Arnold, W. and A.V. Lichtenstein. 1993. Ectoparasite loads decrease the fitness of alpine marmots (*Marmota marmota*) but are not a cost of sociality. Behavioral Ecology 4:36–39.

Bailey, V. 1936. The mammals and life zones of Oregon. North American Fauna 55:1–416.

Bedrosian, G., J.W. Watson, K. Steenhof, M.N. Kochert, C.R. Preston, B. Woodbridge, G.E. Williams, K.R. Keller, and R.H. Crandall. 2017. Spatial and temporal patterns in golden eagle diets in the western United States, with implications for conservation planning. Journal of Raptor Research 51(3):347–367.

Beecham, J.J. 1970. Nesting ecology of the golden eagle in southwestern Idaho. M.S. thesis. University of Idaho, Moscow.

Bloom, P.H. and S.J. Hawks. 1982. Food habits of nesting golden eagles in northeast California and northwest Nevada. Journal of Raptor Research 16:110–115.

Blumstein, D.T., A. Ozgul, V. Yovovich, D.H. Van Vuren, and K.B. Armitage. 2006. Effect of predation risk on presence and persistence of yellow-bellied marmot (*Marmota flaviventris*) colonies. Journal of Zoology 270(1):132–138.

Braun, J.K., T.S. Eaton, Jr., and M.A. Mares. 2011. *Marmota caligata*. Mammalian Species 43(884):155–171.

Carey, H.V. 1985. Nutritional ecology of yellow-bellied marmots in the White Mountains of California. Holarctic Ecology 8(4):259–264.

Cockrum, E.L. 1997. Rabies, Lyme Disease, Hanta Virus and other Animal Borne Human Diseases in the United States and Canada. Fisher Books, Tucson, Arizona.

Dalquest, W. W. 1948. Mammals of Washington. University of Kansas Publication, Museum of Natural History 2:1–444.

Davidson, A.D., J.K. Detling, and J.H. Brown. 2012. Ecological roles and conservation challenges of social, burrowing, herbivorous mammals in the world's grasslands. Frontiers in Ecology and the Environment 10(9):477–486.

Dobler, F.C., J. Eby, C. Perry, S. Richardson, and M. Vander Haegen. 1996. Status of Washington's shrub-steppe ecosystem: extent, ownership, and wildlife/vegetation relationships. Research report. Washington Department of Fish and Wildlife, Olympia.

Edwards, C.C. 1969. Winter behavior and population dynamics of American eagles in western Utah. Ph.D. thesis. Brigham Young University, Provo, Utah.

Florant, G.L., L.C. Nuttle, D.E. Mullinex, and D.A. Rintoul. 1990. Plasma and white adipose tissue lipid composition in marmots. American Journal of Physiology 258:R1123–R1131.

Floyd C.H., D.H. Van Vuren, and B. May. 2005. Marmots on Great Basin mountaintops: using genetics to test a biogeographic paradigm. Ecology 86:2145–2153.

Frase, B.A. and K.B. Armitage. 1989. Yellow-bellied marmots are generalist herbivores. Ethology, Ecology and Evolution 1:353–366.

Frase, B.A. and R.S. Hoffmann. 1980. *Marmota flaviventris.* Mammalian Species 135:1–8.

Hayden, S.L. 1984. Winter food habits and ecology of golden and bald eagles in northeastern Wyoming. M.S. thesis. University of Wyoming, Laramie.

Herring, G., C.A. Eagles-Smith, and J. Buck. 2017. Characterizing golden eagle risk to lead and anticoagulant rodenticide exposure: a review. Journal of Raptor Research 51(3):273–292.

Hickman, G.L. 1968. The ecology and breeding biology of the golden eagle in southwestern Idaho and southeastern Oregon. U.S.D.I. Bureau of Sport Fisheries and Wildlife, Division of Wildlife Services. Unpublished report.

Hoffman, R.S. 1974. Terrestrial vertebrates. Pp. 475–568 *in* J. Ives and R. Barry (eds.). Arctic and Alpine Environments. Metheun, London.

IDFG (Idaho Department of Fish and Game). 2017. Idaho State Wildlife Action Plan, 2015. Idaho Department of Fish and Game, Boise. Grant No.: F14AF01068 Amendment #1. Sponsored by the US Fish and Wildlife Service, Wildlife and Sport Fish Restoration Program. Available online at: *http://fishandgame.idaho.gov/* (last accessed August 1, 2017).

Inouye, D.W., B. Barr, K.B. Armitage, and B.D. Inouye. 2000. Climate change is affecting altitudinal migrants and hibernating species. Proceedings of the National Academy of Sciences of the United States of America. 97(4):1630–1633.

IUCN (International Union for Conservation of Nature). 2017. Available online at: *http://www.iucnredlist.org* (last accessed July 31, 2017).

Johns, D.W. and K.B. Armitage. 1979. Behavioral ecology of alpine yellow-bellied marmots. Behavioral Ecology and Sociobiology 5(2):133–157.

Jones, C.G., J.H. Lawton, and M. Shachak. 1994. Organisms as ecosystem engineers. Oikos 69(3):373–386.

Keller, K.R. 2015. Golden eagle nesting survey report for the central Utah study area, March–July 2015. Report submitted to the Utah Division of Wildlife Resources and Natural Resources Department, U.S. Army, Dugway Proving Ground.

Kilgore, D.L., Jr. 1972. Energy dynamics of the yellow-bellied marmot (*Marmota flaviventris*): a hibernator. Ph.D. dissertation. University of Kansas, Lawrence.

Knight, R.L. and A.W. Erickson. 1978. Marmots as a food source of golden eagles along the Columbia River. Murrelet 59:28–30.

Kochert, M.N. 1972. Population status and chemical contamination in golden eagles in southwestern Idaho. M.S. thesis. University of Idaho, Moscow.

Marr, N.V. and R.L. Knight. 1983. Food habits of golden eagles in eastern Washington. Murrelet 64:73–77.

Marsh, R.E. 1984. Ground squirrels, prairie dogs and marmots as pests on rangeland. Proceedings of the Vertebrate Pest Conference 11:195–208.

Marzluff, J.M., S.T. Knick, M.S. Vekasy, L.S. Schueck, and T.J. Zarriello. 1997. Spatial use and habitat selection of golden eagles in southwestern Idaho. Auk 114(4):673–687.

McGahan, J. 1968. Ecology of the golden eagle. Auk 85:1–12.

McIntyre, C.L. and L.G. Adams. 1999. Reproductive characteristics of migratory golden eagles in Denali National Park, Alaska. The Condor 101(1):115–123.

Melcher, J.C., K.B. Armitage, and W.P. Porter. 1990. Thermal influences on the activity and energetics of yellow-bellied marmots (*Marmota flaviventris*). Physiological Zoology 63(4):803–820.

NatureServe. 2017. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available online at: *http://explorer.natureserve.org* (last accessed July 31, 2017).

Nelson, B.C. 1980. Plague studies in California—the roles of various species of sylvatic rodents in plague ecology in California. Proceedings of the 9th Vertebrate Pest Conference. Paper 30.

NMDGF (New Mexico Department of Game and Fish). 2016. State Wildlife Action Plan for New Mexico. New Mexico Department of Game and Fish, Santa Fe.

Oli, M.K. and K.B. Armitage. 2004. Yellow-bellied marmot population dynamics: demographic mechanisms of growth and decline. Ecology 85(9):2446–2455.

Ozgul, A., D.Z. Childs, M.K. Oli, K.B. Armitage, D.T. Blumstein, L.E. Olson, S. Tuljapurkar, and T. Coulson. 2010. Coupled dynamics of body mass and population growth in response to environmental change. Nature 466:482–487.

Reynolds, H.V., III. 1969. Population status of the golden eagle in south-central Montana. M.S. thesis. University of Montana, Missoula.

Schwartz, O.A. and K.B. Armitage 1989. Density-independent correlates of life history characteristics of yellow-bellied marmots. Sixty-ninth Ann. Meet. Am. Soc. of Mammal. Abstract.

Schwartz, O.A., K.B Armitage, and D. Van Vuren. 1998. A 32-year demography of yellow-bellied marmots. Journal of Zoology 246:337–346.

Schwartz, O.A. and K.B. Armitage. 2005. Weather influences on demography of the yellow-bellied marmot (*Marmota flaviventris*). Journal of Zoology 265:73–79.

Schweiger, A., H-J. Fünfstück, and C. Beierkuhnlein. 2015. Availability of optimal-sized prey affects global distribution patterns of the golden eagle *Aquila chrysaetos*. Journal of Avian Biology 46:81–88.

Stallman, E.L. and W.G. Holmes. 2002. Selective foraging and food distribution of high-elevation yellow-bellied marmots (*Marmota flaviventris*). Journal of Mammalogy 83(2):576–584.

Thompson, S.E., Jr. 1979. Socioecology of the yellow-bellied marmot (*Marmota flaviventris*) in central Oregon. University of California, Berkeley.

Thompson, S.P., R.S. Johnstone, and C.D. Littlefield. 1982. Nesting history of golden eagles in Malheur-Harney Lakes Basin, southeastern Oregon. Raptor Research 16:116–122.

Travis, S.E. and K.B. Armitage. 1972. Some quantitative aspects of the behavior of marmots. Transactions of the Kansas Academy of Science (1903–). 75(4):308–321.

USDA (U.S. Department of Agriculture, Animal and Plant Inspection Service, Wildlife Services). 2003. Rodent Damage Management in Idaho: Environmental Assessment.

USGS-GAP (U.S. Geological Survey Gap Analysis Program). 2013. National Species Distribution Models. http://gapanalysis.usgs.gov (last accessed August 14, 2017).

Van Vuren, D. 1996. Ectoparasites, fitness, and social behaviour of yellow-bellied marmots. Ethology 102:686–694.

Van Vuren, D.H. 2001. Predation on yellow-bellied marmots (*Marmota flaviventris*). American Midland Naturalist 145:94–100.

Van Vuren, D. and K.B. Armitage. 1991. Duration of snowcover and its influence on life-history variation in yellow-bellied marmots. Canadian Journal of Zoology 69:1755–1758.

Verts, B.J. and L.N. Carraway. 1998. Land Mammals of Oregon. University of California Press, Ltd., Berkeley and Los Angeles, California.

VPCRAC (Vertebrate Pest Control Research Advisory Committee). 2014. Marmot. *In* Vertebrate Pest Control Handbook Online, Chapter 4, Part 3. Available online at *http://www.vpcrac.org/about/vertebrate-pest-handbook/* (last accessed August 1, 2017).

Ward, J.M., Jr. 1980. Physiological ecology of the yellow-bellied marmot. Ph.D. dissertation. University of Kansas, Lawrence.

Watson, J. 2010. The Golden Eagle. Yale University Press, New Haven, Connecticut.

Watson, J.W. and R.W. Davies. 2015. Comparative diets of nesting golden eagles in the Columbia Basin between 2007–2013 and the late 1970s. Northwestern Naturalist 96(1):81–86.

WDFW (Washington Department of Fish and Wildlife). 2015. Washington's State Wildlife Action Plan: 2015 update. Washington Department of Fish and Wildlife, Olympia, Washington.

White, T.C.R. 2011. The significance of unripe seeds and animal tissues in the protein nutrition of herbivores. Biological Reviews 86:217–224.

Woodgerd, W. 1952. Food habits of the golden eagle. Journal of Wildlife Management 16(4):457–459.

Appendix 1: Conservation Status of Yellow-Bellied Marmots 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	No mention	No mention
California	Unranked	No mention	Open all year; no limit
Colorado	Secure	No mention	Aug 10–Oct 15; 2/day
Idaho	Secure	No mention (*M. caligata* is Tier 3: not a priority but has conservation needs)	Open all year; no limit
Kansas	No status provided (outside range)	N/A	N/A
Montana	Secure (*M. caligata* Vulnerable/Apparently Secure)	No mention (*M. caligata* lacks a baseline survey and needs to be targeted for survey and inventory)	Open all year; no limit
Nebraska	No status provided (outside range)	N/A	N/A
Nevada	Apparently Secure	Not a species of conservation priority	No mention
New Mexico	Imperiled	No mention	No mention
North Dakota	No status provided (outside range)	N/A	N/A
Oklahoma	No status provided (outside range)	N/A	N/A
Oregon	Apparently Secure	Not a conservation strategy species	Open all year; no limit
South Dakota	Secure	No mention	Open all year; no limit
Texas	No status provided (outside range)	N/A	N/A
Utah	Apparently Secure/Secure	No mention	Open all year; no limit
Washington	Apparently Secure	No mention (*M. olympus* a Species of Greatest Conservation Need)	Open all year; no limit (*M. caligata* and *M. olympus* protected)
Wyoming	Secure	No mention	No mention