Chapter 11
Quails

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Abstract Six species of quails occur on western United States (U.S.) rangelands: northern bobwhite, scaled quail, Gambel's quail, California quail, Montezuma quail, and mountain quail. These quails are found across a variety of vegetation types ranging from grasslands to mountain shrublands to coniferous woodlands. Given their ecological importance and gamebird status, there is considerable conservation, management, and research interest by ecologists and the public. Western quails in general are *r*-selected species whose populations are strongly influenced by weather. Based on Breeding Bird Survey data, 3 species are declining (northern bobwhite, scaled quail, and mountain quail), 2 species have inconclusive data (Gambel's quail

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and Montezuma quail), and 1 species is increasing (California quail). Grazing represents a valuable practice that can be used to create or maintain quail habitat on western rangelands if applied appropriately for a given species, site productivity, and prevailing climate. Invasive, nonnative grasses represent a notable threat to quails and their habitat given the negative influence that nonnative grasses have on the taxon. Numerous conservation programs exist for public and privately-owned rangelands with potential to create thousands of hectares of habitat for western quails. Although the taxon is relatively well-studied as a group, additional research is needed to quantify the cumulative impact of climate change, landscape alterations, and demographic processes on quail-population viability. In addition, research on quail response to rangeland-management practices is limited in scope (only 1–2 species) and geographic extent (mostly Texas, Oklahoma, and New Mexico) and warrants further investigation.

Keywords California quail · Gambel's quail · Grazing · Montezuma quail · Mountain quail · Nonnative grasses · Northern bobwhite · Quails · Rainfall · Scaled quail

11.1 General Life History and Population Dynamics

Quails and quail hunting represent an important component of the culture and economy of rural communities throughout the western United States (U.S.). Each year, thousands of quail hunters venture onto western rangelands for the opportunity to hunt wild quails. The popularity of quail hunting in western states extends not only from the beautiful landscapes that western rangelands provide for upland gamebird hunting but also from the rich diversity of quails. Six quail species occur in the U.S., and all 6 species are found on western rangelands. The 6 species of quail occur in 4 genera (*Colinus*, *Callipepla*, *Cyrtonyx*, and *Oreortyx*) and are classified within the order Galliformes, family Odontophoridae, and sub-family Odontophorinae. These quails are found across a variety of vegetation types in the U.S. ranging from grasslands to mountain shrublands to coniferous woodlands and consist of the northern bobwhite (*Colinus virginianus*), scaled quail (*Callipepla squamata*), Gambel's quail (*Callipepla gambelii*), California quail (*Callipepla californica*), Montezuma quail (*Cyrtonyx montezumae*), and mountain quail (*Oreortyx pictus*; Fig. 11.1a–f). Western quails are *r*-selected species whose populations are strongly influenced by weather, particularly rainfall (Brennan 2007).

Given the diversity of quails that occur on western rangelands, it is impractical to discuss each species' life history, ecology, and management. Consequently, we synthesize the literature on quails and provide generalizations of life history, ecology, and management for this taxon, acknowledging that individual species may show deviations from generalizations. In cases where such deviations are notable, we

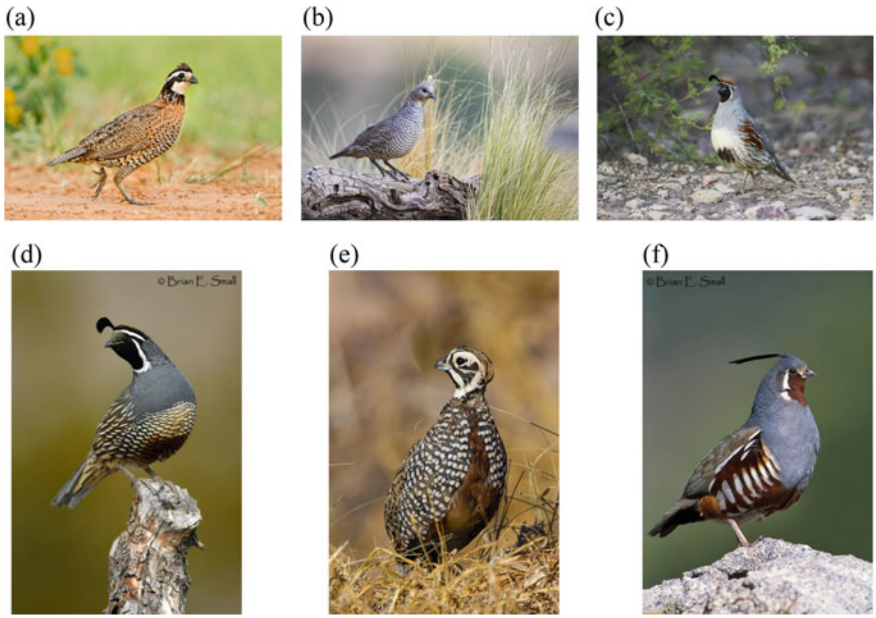

Fig. 11.1 Six quail species inhabit the western rangelands of the United States. These quails are **a** northern bobwhite, **b** scaled quail, **c** Gambel's quail, **d** California quail, **e** Montezuma quail, and **f** mountain quail. Photographs by Larry Ditto (northern bobwhite, scaled quail, Gambel's quail, and Montezuma quail) and Brian Small (California quail and mountain quail)

reference the species. In addition, of the 6 quail species, northern bobwhite is the only species that also occurs in the eastern U.S. In this chapter, we focus on the ecology and management of northern bobwhite as it pertains to the western portion of its geographic distribution.

11.1.1 Nesting

Nesting season for quails generally begins shortly after covey break-up in the spring when males leave winter coveys and begin seeking female mates from other coveys (Gullion 1962; Gee et al. 2020; Table 11.1). Pair formation takes place generally 2–3 weeks prior to nesting but can occur much earlier (Gullion 1962; Wallmo 1954). Nests are usually built on the ground beneath herbaceous, succulent, or shrubby vegetation providing both security and thermal cover (Pope 2002; Stromberg et al. 2020). Although herbaceous cover is an important component of nest concealment, Gambel's quail have adapted to desert environments lacking such cover (Gee et al. 2020) and instead rely on cryptic coloration of the eggshells to reduce the probability of detection (Brennan 2007). Quails also select nesting structure depending on annual availability. For example, mountain quail in west-central Idaho relied more on woody cover for nesting and brood-rearing during a drier-than-average year but used more herbaceous cover in a wetter-than-normal year (Reese et al. 2005). Nest success varies greatly among species and within populations through time and space (Table 11.1).

11.1.2 Brood-Rearing

Female quail generally lay one egg per day to every other day until the clutch is complete ($\approx$ 12–14 eggs), with nest incubation initiating soon thereafter and lasting 21–26 days (Table 11.1). Both parents tend to incubate the clutch and care for the chicks, but the degree of care varies by species (Brennan 2007; Gutiérrez 1980). Quails traditionally have been considered monogamous and, of the 6 species, mountain quail likely are the most monogamous (Beck et al. 2005). However, ambisexual polyandry (i.e., one female mating with more than one male) is common and has been documented in several species. Both males and females are known to incubate and raise broods with more than one mate during the breeding season (Curtis et al. 1993; Brennan 2007; Davis et al. 2017). In addition, a small portion of the breeding population often produces multiple broods (i.e., individuals raising more than 1 brood per nesting season), at least in California quail (Francis 1965), Gambel's quail (Gullion 1956), and northern bobwhite (Guthery and Kuvlesky 1998). However, the influence of multiple broods on annual populations is likely insignificant because second and third broods contribute little to age ratios under a typical probability of nest success (Guthery and Kuvlesky 1998). In contrast to an ambisexual polyandry approach, female mountain quail lay two simultaneous clutches, incubated separately by the male and female in each monogamous pair and thereby optimize breeding success in mountainous areas typified by short growing seasons (Beck et al. 2005).

11.1.3 Brood Success and Chick Survival

Brood success and chick survival vary among quails and likely is related to habitat and weather conditions (Brennan 2007). Chicks of all quail species are precocial and susceptible to a variety of mortality sources such as predation and exposure to inclement weather. In mesic environments, exposure to rain during the first weeks of life has been associated with chick mortality (Terhune et al. 2019). In xeric environments, Heffelfinger et al. (1999) documented that hot, dry summer weather reduced the percent of juveniles in Gambel's quail populations in Arizona compared to cool, wet weather and speculated that reduced food availability reduced juvenile survival. Chick survival can have a significant impact on quail population dynamics, although less so than adult survival (Guthery and Kuvlesky 1998; Sandercock et al. 2008).

Table 11.1 General life history characteristics of 6 quail species inhabiting rangelands of the western United States

Common name	Scientific name	Critical precipitation	Covey breakup	Nesting	Clutch size	Nest success	Annual survival	Average life span
Northern bobwhite[a]	*Colinus virginianus*	Variable by region	Feb–Mar	May–Sep	7–28 eggs	35–45%	18–30%	< 1 year
Scaled quail[b]	*Callipepla squamata*	Jan–Jul	Feb–Mar	Apr–Sep	5–22 eggs	16–83%	14–17%	1–2 years
Gambel's quail[c]	*Callipepla gambelii*	Oct–Mar	Feb–Mar	Apr–Jun	5–20 eggs	No data available	10–60%	1.5 years
California quail[d]	*Callipepla californica*	Sep–Apr	Feb	May–Jul	1–26 eggs	5–30%	8–50%	No data available
Montezuma quail[e]	*Cyrtonyx montezumae*	Jul–Sep	Feb	Jul–Sep	2–15 eggs	12–75%	18–59%	No data available
Mountain quail[f]	*Oreortyx pictus*	Jan–Mar	Jan	Apr–Jun	6–14 eggs	70–76%	17–42%	No data available

[a] Brennan et al. (2020)
[b] Dabbert et al. (2020)
[c] Gee et al. (2020)
[d] Calkins et al. (2020)
[e] Stromberg et al. (2020)
[f] Gutiérrez and Delehanty (2020), Stephenson et al. (2011)

Reliable estimates of chick survival generally are lacking due to the difficulties in capturing and monitoring juvenile quail of all species; however, research on chick survival has increased during recent years given advances in technology (e.g., Orange et al. 2016; Terhune et al. 2019).

11.1.4 Non-breeding

Quails are gregarious species, and the covey is the primary social unit during much of the year.

Covey sizes generally are largest after brooding season (autumn). Depending on the species, autumn coveys are composed of 1 or more adult pairs and their broods, and covey sizes may range from 8 to 30 individuals. Covey sizes of Montezuma and mountain quail occur at the lower end of this range, whereas Gambel's and scaled quail occur at the upper end (Brennan 2007; Gutiérrez and Delehanty 2020). Whether in coveys or not, quails roost together at night. Quails most often roost on the ground in grass or shrubby ground cover, although Gambel's and California quail prefer to roost above ground in dense shrubs or trees (Gee et al. 2020; Calkins et al. 2020). Quails generally leave the roost shortly after sunrise to begin feeding (Gutiérrez and Delehanty 2020; Stromberg et al. 2020). Communal roosting and feeding presumably provides both thermal protection and enhanced predator detection (Anderson 1974).

11.1.5 Survival and Sources of Mortality

Annual survival of quails generally is low (< 20%) but varies among and within species (≈ 10–70%) and is considered a primary driver of populations (Guthery and Kuvlesky 1998; Sandercock et al. 2008; Table 11.1). Sources of adult quail mortality may include predation, exposure to weather and extreme temperature, disease, parasites, and starvation. Habitat quality and availability can exacerbate or ameliorate the effects of each of these (Brennan 2007). Mammalian predators are the primary predators of nests, whereas raptors pose the greatest threat to adults (Brennan 2007; Turner et al. 2014).

Similar to other Galliformes, quails tend to walk or run more often than fly and usually respond to potential predators with some variation of a "run and hide" escape strategy. For example, scaled quail will often run from potential predators and then, when pressured, fly long distances to hide (Dabbert et al. 2020). In contrast, Montezuma quail tend to crouch and hide in response to danger, relying on their cryptic coloration to prevent detection. Montezuma quail flush only when approached closely and fly short distances to again hide in the relatively dense oak (*Quercus*)-juniper (*Juniperus*) savanna they inhabit (Stromberg 1990). The other quails exhibit some variation between these two extremes, and the escape strategies they exhibit appear adapted to the habitat in which they evolved. For example, Montezuma quail will crouch and hide rather than fly even when found in areas lacking cover (Brown 1982; Stromberg 1990).

11.1.6 Seasonal Movements and Dispersal

Quails tend to be less mobile than other gallinaceous birds. Maximum annual movements of coveys < 4 km have been reported for several species (Stromberg 1990; Gee et al. 2020). Although quails are not known to migrate in a strict sense, mountain quail move seasonally between winter and breeding habitat presumably to avoid snow accumulation at higher elevations (Gutiérrez and Delehanty 2020). Similarly, scaled quail in the northern portions of their distribution are reported to make short (< 4 km) movements between summer and winter ranges (Dabbert et al. 2020). Information on movements from nesting to brood-rearing cover is limited. Large movements (e.g., > 20 km) by quails have been reported and may be associated with dispersing males (Campbell and Harris 1965 but see Townsend et al. 2003).

11.1.7 Population Dynamics

Quails are *r*-selected species (Guthery and Brennan 2007), and their population fluctuations are largely determined by weather (Brennan 2007). Variations in demographic parameters such as percent hens nesting, nesting rate, and nest success, combined with low annual survival, create conditions for fluctuating quail populations that are subject to the vagaries of habitat and weather conditions (Table 11.1). Given their low survival, quail population fluctuations largely are the result of varying reproductive success. For example, Swank and Gallizioli (1954) reported that 90% of the variation in Gambel's quail population indices were attributed to nesting success. Hernández et al. (2005) documented a lower percentage of northern bobwhite hens nesting, lower nesting rates, and shorter nesting seasons during drought compared to wet years. Consequently, in years of poor environmental conditions, quail numbers drop significantly only to rebound when conditions improve, resulting in "boom and bust" population dynamics (Hernández and Peterson 2007).

The reproductive success of quails that inhabit semiarid environments has been positively correlated with rainfall (Bridges et al. 2001; Hernández et al. 2005; Brennan 2007). The ideal timing for rainfall varies by species but generally occurs 1–3 months prior to the nesting season (Table 11.1). For example, northern bobwhite occurs over a wide range of vegetation types, and the months of critical rainfall as well as the relative influence of rainfall varies by region (Bridges et al. 2001; Hernández and Peterson 2007). Other researchers have explored the relationship between quail reproductive success and heat indices (Francis 1970; Heffelfinger et al. 1999) and have documented that cooler summer temperatures can have an ameliorating effect on drought with respect to quail reproduction (Heffelfinger et al. 1999).

The mechanism by which weather exerts its influence on quail reproduction presently is unknown (Hernández et al. 2002) but often attributed to the materialized effects of rainfall (e.g., increased food, nesting cover, etc.; Brennan 2007). For Gambel's quail, forb growth that proliferates after favorable winter rains is presumed to provide higher levels of Vitamin A, which is thought to stimulate reproductive organ development and positively influence reproductive success (Hungerford 1960, 1964). However, this relationship has not been empirically established in quails (Lehmann 1953; Guthery 2002). Investigations into other factors that may enhance (e.g., phosphorus) or possibly inhibit (e.g., phytoestrogens) quail reproduction have failed to provide conclusive evidence to explain the boom-and-bust population phenomenon (Cain et al. 1982, 1987). Research that has focused on food and water supplementation also has failed to provide explanatory evidence (Koerth and Guthery 1991; Harveson 1995; Lusk et al. 2002). More recently, thermal stress has been explored as a possible cause of decreased reproductive performance during dry conditions (Guthery et al. 2005) and, of all the proposed mechanisms, this heat-stress hypothesis presently appears the most plausible (Hernández et al. 2002).

11.2 Current Species and Population Status

There is considerable conservation concern among ecologists and the public regarding the population status of quails (Brennan 1991; Church et al. 1993; Hernández et al. 2013). Of the 6 western quails, 3 species are declining (northern bobwhite, scaled quail, and mountain quail), 2 species have inconclusive data (Gambel's quail and Montezuma quail), and 1 species is increasing (California quail; Table 11.2). Currently, none of the western quails are federally listed as endangered or threatened at the species level (Table 11.2). Some species, however, receive special protections at the state level given that most states have their own system for listing species beyond the federal Endangered Species Act. For example, California quail and mountain quail have received focused attention from state agencies due to their popularity (California quail is the official state bird of California) or limited scientific knowledge of their management (mountain quail).

Table 11.2 Conservation status and population trends of quails in the U.S.

Common name	Status	BBS trend (1966–2019)	CBC trend (1993–2019)	Federal status	State status
Northern bobwhite	Declining	− 3.1 (− 3.3, − 2.9)	− 5.25 (− 6.38, − 3.81)	*C. v. ridgwayi* is federally listed	No special status
Scaled quail	Declining	− 0.7 (− 1.6, 0.1)	− 8.11 (− 13.62, − 4.33)	No special status	No special status
Gambel's quail	Inconclusive	0.6 (− 1.8, 2.3)	− 0.88 (− 1.50, − 0.19)	No special status	No special status
California quail	Increasing	0.8 (0.2, 1.4)	1.71 (0.96, 2.51)	No special status	State wildlife action species (CA). *C. c. catalinensis* species of special concern
Montezuma quail	Inconclusive	Sample size too small for trends	3.82 (0.65, 6.98)	No special status	No special status
Mountain quail	Declining	0.0 (− 1.7, 1.3)	− 2.97 (− 5.02, − 0.83)	USFWS[a] determined eastern populations were not threatened (2003)	Species of greatest conservation concern (ID); sensitive species in northern basin (OR); state wildlife action species (NV)

Trends are percent annual change and 95% credible intervals (in parenthesis) as reported by Breeding Bird Surveys (BBS) and Christmas Bird Counts (CBC)
[a]United States Fish and Wildlife Service (USFWS)

11.2.1 Northern Bobwhite

Northern bobwhite have the largest geographic distribution of the 6 quail species. They can be found from the eastern U.S. west to the Great Plains, and from northern U.S. south to southern Mexico (Fig. 11.2A). Northern bobwhite have been declining at least since the early 1900s (Hernández et al. 2013), but ecologists did not take notice and become broadly aware of the continental decline of the species until the end of the century (Brennan 1991). According to data from the North American Breeding Bird Survey (BBS; Sauer et al. 2018), northern bobwhite declined 3.1% per year during 1966–2019 and have become extirpated (i.e., no longer documented during surveys) in the wild in New England states and functionally extirpated in surrounding states (e.g., New York, Pennsylvania, New Jersey; Table 11.2).

The masked bobwhite (*C. v. ridgwayi*), an endangered subspecies of northern bobwhite, possessed a historical geographic distribution that spanned southern

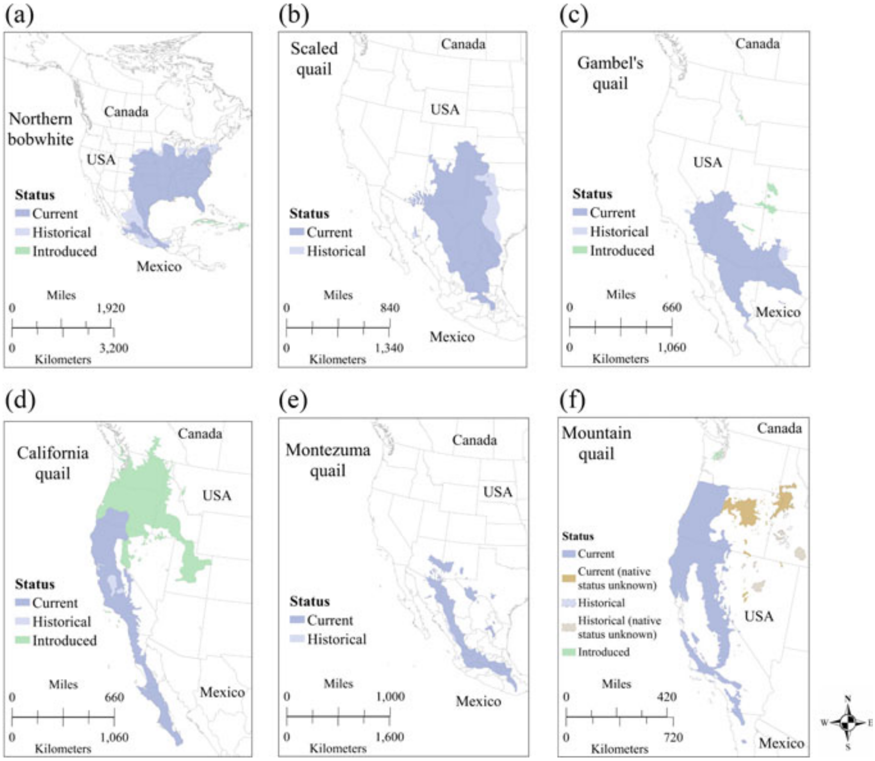

Fig. 11.2 Geographic distribution for **a** northern bobwhite, **b** scaled quail, **c** Gambel's quail, **d** California quail, **e** Montezuma quail, and **f** mountain quail. Historical and current geographic distributions are based on data from the North American Breeding Bird Survey except for Montezuma quail and mountain quail. For Montezuma quail, eBird data were used given the species is not detected during Breeding Bird Surveys. For mountain quail, in addition to data from Breeding Bird Survey, we used eBird data, state agency data (Idaho, Nevada, and Oregon), and Linsdale (1936). Breeding Bird Survey routes where ≥ 1 quail individual was detected were used to define historical (1967–1980) and current (2010–2019) distributions. Introduced geographic distributions represent areas where species have been introduced and formed a sustained population based on Breeding Bird Survey, eBird, and species accounts in the Birds of the World. Additional references consulted for geographic distributions included Guillon and Christiansen (1957), Brown (1989), Brennan (2007), Kamees et al. (2008), California Department of Fish and Wildlife (2017), and Idaho Department of Fish and Game (2019)

Arizona and northern Mexico (Hernández et al. 2006a, b). Today, the masked bobwhite is essentially "extinct" in the wild in the U.S., where populations consist of released captive-raised individuals. The species has not been detected during the BBS and rarely is documented during Christmas Bird Counts. Surveys from Buenos Aires National Wildlife Refuge—the only site where the subspecies is known to occur in the U.S.—indicated a declining trend during 1999–2011 (U.S. Fish and Wildlife Service 2014). Masked bobwhite may still exist in Sonora, Mexico (Hernández et al. 2006a, b).

11.2.2 Scaled Quail

The geographic distribution of scaled quail generally is associated with the Chihuahuan Desert and surrounding desert grasslands and chaparral of the southwestern U.S. (Fig. 11.2b). This species is found from southwestern Kansas and western Texas west to southeastern Arizona, and from southeastern Colorado south to central Mexico. Scaled quail declined 0.7% per year during 1966–2019, according to BBS data (Table 11.2). The chestnut-bellied scaled quail (*C. s. castanogastris*), a subspecies found in southern Texas, has been experiencing notable population declines in recent decades (Hernández et al. In Press).

11.2.3 Gambel's Quail

Gambel's quail possess a geographic distribution that may be described as centered in the Sonoran Desert of Arizona and northern Mexico and radiating from there into the surrounding contiguous states (Fig. 11.2c). Gambel's quail can be found from western Texas along the riparian areas of the Rio Grande River west to southeastern California, and from southwestern Utah south into northern Mexico. The population trend for Gambel's quail is inconclusive based on BBS data (Table 11.2). However, the species faces challenges associated with increased urban development (Zornes and Bishop 2009; Gee et al. 2020), especially solar energy development, the impacts of which are unknown.

11.2.4 California Quail

California quail possess a geographic distribution located along the western coast of the U.S. (Fig. 11.2d). The native geographic distribution of California quail is along the West Coast from southern Oregon, a small portion of western Nevada, south to California, and into Baja California, Mexico (Leopold 1985). However, California quail has been widely introduced throughout much of western North America and now occurs over most of Washington and Oregon, Idaho, Utah, and British Columbia. In contrast to other quail species, California quail increased 0.8% during 1966–2019 according to BBS data (Table 11.2). It is unknown why the species is increasing but may be related to the species' adaptability to human presence, often inhabiting cover adjacent to agricultural lands, riparian corridors, wooded suburbs, and even urban parks.

Similar to northern bobwhite, California quail have a subspecies (Catalina California quail, *C. c. catalinesis*) that receives special protection. The Catalina California quail is an insular subspecies believed to have been introduced to Santa Catalina

Island by Indigenous peoples about 12,000 years ago (Collins 2008; Calkins et al. 2020). This subspecies faces challenges endured by all small, isolated populations (e.g., threat of genetic inbreeding). The current population status of the Catalina California quail is unclear, given that the subspecies has been counted irregularly. Data from BBS indicated a decline from 191 quail in 2013 to 46 quail in 2017.

11.2.5 Montezuma Quail

Montezuma quail may be considered a Mexican species whose northern extent of its geographic distribution extends into southwestern U.S. Most of the Montezuma quail geographic distribution occurs in Mexico, but the species may be found from central and western Texas west to southwestern Arizona (Fig. 11.2e). Similar to Gambel's quail, the Montezuma quail population trend is inconclusive (Table 11.2). However, the species faces challenges, such as genetic erosion, in the easternmost portion of its distribution where the species occurs in relatively isolated populations (Mathur et al. 2019).

11.2.6 Mountain Quail

Of the 6 quail species, mountain quail are the least studied. Mountain quail occur primarily in the Sierra Nevada, Cascade, and Coast Ranges, but disjunct populations also occur in the Intermountain West of Idaho and Nevada as well as the Baja Peninsula (Fig. 11.2f). The species may be found from southern Washington south through western Oregon and western California. According to BBS data, mountain quail declined 0.01% during 1966–2019 (Table 11.2). Mountain quail have received focused attention from state agencies due to the limited scientific knowledge of the species (Pope and Crawford 2004; Reese et al. 2005; Stephenson et al. 2011).

11.3 Population Monitoring

11.3.1 National and Regional Level

Given the wide distribution of quails across the U.S., ecologists have relied on broad-scale datasets such as the BBS and the Audubon Christmas Bird Count (CBC) to monitor their populations. These monitoring programs analyze long-term datasets to estimate bird population trends at various spatial extents (e.g., state, national, Bird Conservation Region, geographic distribution). The BBS was initiated in 1966 to monitor North American bird populations (Sauer et al. 2018) and presently is coordinated by the U.S. Geological Survey. Surveys are conducted annually during the summer along thousands of 39.2-km routes that are distributed across North America. The CBC is coordinated by the National Audubon Society and was initiated in 1900 (Meehan et al. 2018). The CBC is conducted during winter (Dec–Jan) and involves observers counting birds within a 24.1-km diameter "count circle". The BBS and CBC provide complementary sources of information because the former occurs during the breeding season (summer), whereas the latter occurs during the non-breeding season (winter). Because these surveys are collected annually throughout the quails' geographic distributions, ecologists have used these data to understand quail-population response to changes in land use and weather patterns (e.g., Peterson et al. 2002; Murphy 2003; Veech 2006; Janke et al. 2017; Miller et al. 2018).

11.3.2 Ecoregion and Site Level

The BBS and CBC are designed to provide measures of bird populations at large spatial extents (e.g., statewide, multi-state, national). However, the need also exists to monitor quail populations at smaller spatial extents such as within a state or at a site level. The social nature of quails facilitates the monitoring of their populations at these smaller spatial extents. At the state level, state wildlife agencies have used rural mail carrier surveys (Robinson et al. 2000) and roadside surveys (DeMaso et al. 2002) to monitor quail populations. In Kansas, surveys are conducted annually throughout the state during specific weeks of the year by rural mail carriers making deliveries. These volunteers record their observations of quail and distance traveled for five consecutive days, and these data are used to obtain measures of relative abundance (Robinson et al. 2000). This method is very similar to roadside surveys. In Texas and Oklahoma, state agency personnel conduct annual roadside surveys whereby biologists drive along established roadside routes of known length and record the number of quail observed to estimate quail relative abundance for regions within the states (DeMaso et al. 2002).

Methods also exist for monitoring quail populations at a site level. These methods include techniques to obtain measures of relative abundance such as whistle counts (number of males calling per point), covey-call counts (number of calling coveys per point), and roadside counts (number of quail observed per distance traveled), as well as methods to obtain estimates of density or abundance such as distance sampling and mark-recapture, respectively. Recently, helicopter surveys within a distance sampling framework have been used to estimate quail density (Rusk et al. 2007; Schnupp et al. 2013). This recent development has permitted the monitoring of quail populations over relatively larger spatial extents (e.g., 20,000 ha) while reducing the survey effort that would be required with traditional walking transects. For more information on quail surveys and their protocols, we refer the reader to Brennan (2007) and Hernández and Guthery (2012).

11.4 Habitat Associations

Western quails occur across a variety of vegetation types (Fig. 11.3a–f). These include savannas and shrublands (northern bobwhite; Fig. 11.3a), desert grasslands or shrubland (scaled quail; Fig. 11.3b, Gambel's quail: Fig. 11.3c, California quail; Fig. 11.3d), oak-juniper woodlands (Montezuma quail; Fig. 11.3e), and mountain shrubland and regenerating forest (mountain quail; Fig. 11.3f). Because climate largely determines vegetation communities at broad scales, quails occur across a range of environmental and topographic gradients.

Quails are relatively sedentary in nature and therefore occur within plant communities that offer satisfactory food and cover in relatively close proximity (Wallmo 1956; Guthery 1999, Dabbert et al. 2020). Woody cover is a critical habitat component for all quails because it provides both food (e.g., seeds, mast, and leaves) and structure (e.g., roosting, escape, and loafing cover). In extreme climes, woody cover provides a retreat from inclement weather such as blizzards or extreme heat and provides access to food during snow accumulation (Lepper 1978; Reese et al. 2005; Palmer et al. 2021). Generally, quails prefer some mosaic of woody and herbaceous cover to support their daily and seasonal needs, but the specific amount of woody cover used by quails varies by species and scale (Hernández 2020). In addition, the optimal configuration of woody and herbaceous patches possesses "slack" in their arrangement such that a single optimal arrangement does not exist (Guthery 1999),

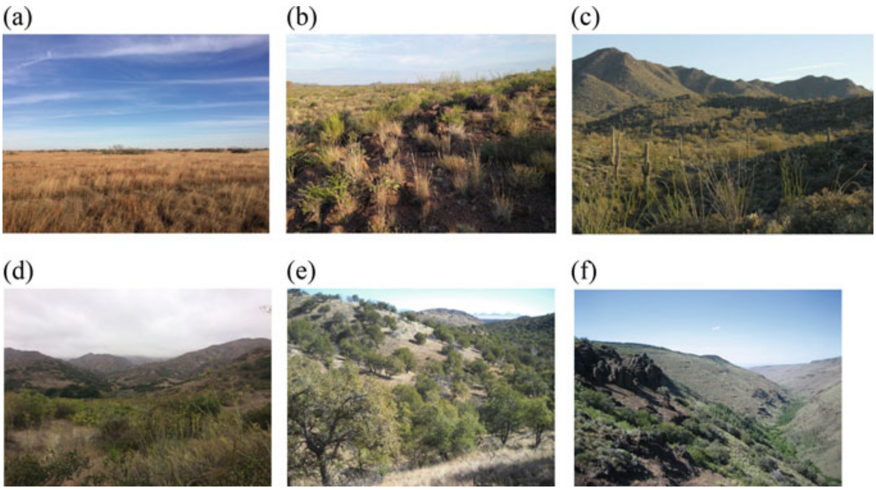

Fig. 11.3 Quail species inhabiting the western rangelands of the United States occur across a variety of vegetation communities as illustrated by typical habitat for **a** northern bobwhite in Texas, **b** scaled quail in Texas, **c** Gambel's quail in Arizona, **d** California quail in California, **e** Montezuma quail in Arizona, and **f** mountain quail in Oregon. Photographs by Fidel Hernández (northern bobwhite), Eric Grahmann (scaled quail), Arizona Game and Fish Department (Gambel's quail), Katherine Miller (California quail), Kirby Bristow (Montezuma quail), and Oregon Department of Fish and Wildlife (mountain quail)

at least for species such as northern bobwhite, scaled quail, and Gambel's quail (Guthery et al. 2001).

Despite these broad habitat commonalities, quail species possess unique habitat affinities and preferences. Following we provide brief descriptions for each species but refer the reader to Brennan et al. (2020), Calkins et al. (2020), Dabbert et al. (2020), Gee et al. (2020), Gutiérrez and Delehanty (2020), and Stromberg et al. (2020) for detailed descriptions.

11.4.1 Northern Bobwhite

Northern bobwhite extend into western rangelands only along the westernmost edge of their geographic distribution. Here, northern bobwhite occur in grasslands, shrublands, and savannas (Fig. 11.3A; Brennan et al. 2020). Northern bobwhite use open ground for travel, herbaceous plants for food and nesting cover, and woody plants for thermal cover and predator protection, as well as nesting (Lehmann 1984; Hernández et al. 2007). Woody cover is important as thermal cover for northern bobwhite in semiarid rangelands, given the regular occurrence of high temperatures and drought (Guthery et al. 2005; Parent et al. 2016).

11.4.2 Scaled Quail, Gambel's Quail, and Masked Bobwhite

Quails of the semiarid southwestern U.S. (Gambel's quail, scaled quail, and masked bobwhite) inhabit desert grasslands, shrublands, brushy arroyos, pinyon (*Pinus* spp.)-juniper woodlands, and chaparral (Anderson 1974; Silvy et al. 2007). These sympatric quails appear to partition available habitat and thereby minimize interspecific competition (Guthery et al. 2001). For example, in Arizona, scaled quail have a stronger grassland association, if a patchy shrub component with minimal tree cover and open bare ground is available (Fig. 11.3b; Bristow and Ockenfels 2006, Dabbert et al. 2020). Gambel's quail evolved in association with thorny legumes, succulents, and scrub-shrub grasslands of the desert (Fig. 11.3c; Brown 1989; Kuvlesky et al. 2007; Gee et al. 2020). This species tends to inhabit areas with more woody cover than either scaled quail or masked bobwhite and prefers mesquite-rimmed riparian areas, particularly along the southern limits of its geographic distribution (Guthery et al. 2001; Ortega-Sánchez 2006; Kuvlesky et al. 2007). Masked bobwhite habitat is characterized by more herbaceous cover and less bare ground relative to Gambel's and scaled quail (Goodwin and Hungerford 1977; Guthery et al. 2001).

11.4.3 California Quail

California quail is an adaptable species that is associated with brushy cover such as riparian edges, foothill woodlands, chaparral, sagebrush (*Artemisia* spp.), grassland oak, and recently disturbed or converted forest (Fig. 11.3d; Leopold 1985; Calkins et al. 2020). California quail also occur along the edges of urban areas such as suburban neighborhoods and apparently do well in such environments (Iknayan et al. 2021); however, the species has been harmed by certain levels of urbanization (Crooks et al. 2004). California quail need access to early successional habitat for foraging, but these early seral stages must be intermixed with woody cover (Koford 1987; Calkins et al. 2020). In the rangelands of the Great Basin, California quail rely on areas of dense shrub such as willows (*Salix* spp.), thorny shrub thickets, saltbush (*Atriplex* spp.), and junipers for protection from snowfall (Nielson 1952; Jewett et al. 1953; Brown 1989).

11.4.4 Montezuma Quail

Montezuma quail occur at higher elevations than other quail species of the southwestern U.S. The species is strongly associated with oak and pine (*Pinus* spp.) woodlands possessing an understory of tall, perennial bunchgrasses and typically inhabit steep, rugged slopes (Fig. 11.3e; Leopold and McCabe 1957; Harveson et al. 2007). An important component of Montezuma quail habitat is the availability of corms, tubers, bulbs, and rhizomes that primarily compose their diet (Hernández et al. 2006a, b; Harveson et al. 2007).

11.4.5 Mountain Quail

Mountain quail prefer steep, shrub-dominated slopes and generally avoid grassland habitats (Fig. 11.3f; Brennan et al. 1987; Gutiérrez and Delehanty 2020). Examples of shrub-dominated communities include chaparral, mixed desert scrub, and early-successional-stage shrub vegetation following disturbance (e.g., fire, logging) (Gutiérrez and Delehanty 2020). Mountain quail may also be found in mixed evergreen-hardwood forests and montane conifer forests (Gutiérrez and Delehanty 2020). Although this species may not strictly inhabit what may be considered typical rangeland environments, the eastern extent of its geographic distribution includes rangelands in the Great Basin (Pope 2002) and western Idaho (Beck et al. 2005; Reese et al. 2005). Here, mountain quail can be found in association with pinyon-juniper, aspen (*Populus* spp.)-sagebrush, shrub-steppe, and riparian areas that are generally steep, rugged, and brushy (Gutiérrez 1980; Brennan et al. 1987; Gutiérrez and Delehanty 2020).

11.5 Rangeland Management

11.5.1 Livestock Grazing

Livestock grazing can be a useful tool for managing quail habitat. Like other rangeland management practices such as prescribed fire or brush management, how the practice is applied and where it is applied will determine whether the effect is positive or negative for quails. In xeric environments, excessive grazing can reduce critical cover (e.g., nesting, escape, thermal, etc.) for quails (Ortega-S and Bryant 2005). Conversely, in more mesic environments, livestock grazing can be a valuable tool for reducing dense, rank vegetation while increasing forb abundance and diversity (Holechek 1981; Grahmann et al. 2018). Overall, livestock grazing can be a useful tool to manage quail habitat, but the impact it will have on quail habitat depends on factors such as grazing intensity, rangeland site productivity, and climate regimes.

The perceived impact of livestock grazing on wildlife habitat has traditionally differed between areas dominated by private lands and areas comprised of mostly public lands. For example, Texas is 95% privately owned and possesses large contiguous tracts of native rangelands where northern bobwhite, scaled quail, Montezuma quail, and Gambel's quail occur. Privately owned ranches in areas such as the Rio Grande Plains and the Rolling Plains of Texas benefit from fee-lease hunting for quails (Hernández et al. 2002) and applying grazing strategies that benefit quail habitat therefore directly contributes to their financial success. These grazing strategies include reduced stocking rates (number of animal units per area per time) and grazing stockers (weaned, yearling cattle) rather than cow-calf pairs. Grazing with stockers is a more quail-friendly strategy because stockers generally are grazed during spring–summer and sold during autumn but can be sold any time during the grazing period should drought occur and forage become limited. Consequently, adjustments in stocking rates can be made more promptly and easily when grazing stockers than cow-calf pairs because the latter involves consideration of the reproductive phase (gestation, weaning, etc.) of the cattle among other logistical and financial considerations. In Texas, grazing is an important habitat management tool for quails that supports privately-operated hunting operations (Brennan 2007; Hernández and Guthery 2012). In contrast, the effects of livestock grazing on wildlife habitat in western states dominated by public land has been contentious. This is likely due to public land agencies in the West being charged to manage lands for multiple uses such as recreation, oil-and-gas production, mining, timber, and wildlife (Brown et al. 1993; Krausman 1996).

The impact of grazing on quails varies by species given their unique ecology and environment they inhabit. Of the 6 quails, masked bobwhite and Montezuma quail exhibit the highest sensitivity to grazing, whereas Gambel's quail exhibits the least sensitivity. Overgrazing has been attributed to the near extinction of masked bobwhite (Kuvlesky et al. 2000; Hernández et al. 2006a, b). The effect of grazing on masked bobwhites likely is exacerbated by the arid climate the subspecies inhabits in Arizona and Sonora, Mexico. These areas experience drought and low herbaceous productivity. The floodplains and drainages that support herbaceous vegetation are preferred by masked bobwhites and cattle, thereby creating conflicts in use between the two (Kuvlesky et al. 2000). Consequently, grazing is prohibited in the Buenos Aries National Wildlife Refuge, the only location in the U.S. where the masked bobwhite occurs (USFWS 2014). Grazing also can negatively affect Montezuma quail because grazing may result in the loss of herbaceous cover, which is critical for this species for nesting, thermal, and hiding cover (Stromberg 1990). If herbaceous cover is severely reduced by livestock, local extirpations may occur (Brown 1982). Similarly, grazing has been cited as a contributing factor to the loss of mountain quail in Idaho resulting from the loss of herbaceous cover and plant diversity in the low-elevation riparian areas inhabited by mountain quail during winter (Brennan 1994).

Although grazing livestock has the ability to negative impact quail habitat and their populations, it also has the ability to have a positive impact if applied appropriately for the climate and site productivity present. Leopold (1985) noted that livestock grazing was necessary to reduce herbaceous cover and increase forb abundance for California quail in the coastal ranges and Sacramento Valley foothills of California where precipitation was higher (Leopold 1985). In southern Texas, livestock grazing also may be beneficial to scaled quail and northern bobwhite, particularly in rangelands dominated by nonnative grasses. Scaled quail strongly avoid dense monocultures of nonnative grasses, and grazing can be used to increase bare ground and forb diversity for both scaled quail (Fulbright et al. 2019; Kline et al. 2019) and northern bobwhite (Grahmann et al. 2018). It is important to note that, even in native rangeland, grazing and quail presence can be compatible if properly managed. For example, northern bobwhite has persisted for decades in huntable numbers over millions of hectares in Texas ecoregions (i.e., the Rolling Plains and Rio Grande Plains) where grazing is a dominant land use (Hernández et al. 2002).

Proper grazing management for quails depends on applying the appropriate grazing pressure to match a site's productivity. Higher grazing pressure may be possible in more mesic and productive sites whereas lower or no grazing pressure may be appropriate for more xeric and lower productivity sites (Spears et al. 1993). Balancing quail habitat and livestock use is possible by using appropriate and flexible stocking rates to always ensure sufficient herbaceous cover for quails across space and time, including during drought (Hernández and Guthery 2012; Bruno 2018).

11.5.2 Other Rangeland Management Practices

Except for northern bobwhite, little research exists on the use of rangeland management practices such as prescribed fire, mechanical treatments, and chemical treatments to manage quail habitat. This research focus on northern bobwhite likely is due to its inhabiting primarily private lands (in the western portion of its geographic distribution) where its long history as an important gamebird provides strong economic, cultural, and ecological incentives for landowners, state agencies, and non-governmental organizations to purposefully manage the species. The other five western quails occur mostly in states dominated by public land where users are the general public and therefore the incentives for active management are considerably fewer. Consequently, management for most western quails besides northern bobwhite tends to be accidental rather than purposeful (Brennan 2007).

Regarding northern bobwhite, research on the impacts of rangeland-management practices has been limited in geographic extent (mostly Texas, Oklahoma, New Mexico; Hernández et al. 2002) and has been discussed in detail elsewhere (Guthery 2000; Brennan 2007; Hernández and Guthery 2012). Brennan (2007) includes the sparse research that exists on the impacts of rangeland management on some of the other western quails, and Hernández and Guthery (2012) provides detailed discussion on the use of prescribed fire, mechanical treatments (e.g., root-plowing, roller-chopping, chaining, grubbing, etc.), and chemical treatments (herbicides, equipment, patterns of application, etc.) for northern bobwhite. We refer the reader to these publications for such information but provide the following general recommendations regarding the use of these or any other rangeland management practice for quail-habitat management.

Rangeland management practices for quails should be implemented in a manner that (1) preserves uncommon or rare vegetation community types present on the site, (2) treats smaller portions (e.g., 120 ha) of more pastures rather than larger portions (e.g., 500 ha) of fewer pastures, (3) treats areas of the same pasture with different but appropriate methods, and (4) treats different areas in different years (Hernández and Guthery 2012). The general goal of such a rangeland-management approach is the promotion of rangeland heterogeneity. Regarding determination of the appropriate rangeland-management practice for a given situation, the decision requires (1) an understanding of plant-community response based on soils and management techniques, (2) knowledge of the amount of the target cover present on the rangeland relative to quail requirements, and (3) some reasonable prediction of the desired outcome (Hernández et al. In Press).

We conclude this section with a brief discussion of a management practice that has generated perennial interest in the management of western quails: water provision. This long-time interest in water provision likely is the result of the semiarid and desert environments that western quails inhabit and the common observation of quails at watering sources. Guzzlers generally are means through which water is provided to western quails, and their use has been evaluated in several species including scaled quail (Rollins et al. 2009), Gambel's quail (Campbell 1960), and mountain quail (Delehanty et al. 2004). Research suggests that, despite the common use of guzzlers by quails, guzzlers do not influence quail vital rates (i.e., adult survival, nest survival) and therefore a practice that likely is of limited value for western quails from a population-response perspective (Campbell 1960; Tanner et al. 2015).

11.6 Effects of Disease

There is no direct association involving livestock as a causative agent for disease in quails. However, parasitic infections and disease research has made a resurgence in the past decade, particularly in Texas for northern bobwhite (Dunham et al. 2014; Bruno et al. 2018) and to a lesser extent scaled quail (Fedynich et al. 2019). Beyond this regional emphasis, quail disease research is scattered across the West with some focus on Gambel's quail in Arizona and New Mexico, and mountain and California quail in California, Oregon, and Washington. However, none of these species has been investigated for parasites and disease in the last 2–3 decades. Given the recent documentation of parasites and diseases in northern bobwhite (Dunham et al. 2014; Bruno et al. 2018), we provide a brief overview of quail parasites and their documented impact on quails.

11.6.1 Microparasites

Parasites can be categorized into microparasites (bacteria, viruses, and fungi) and macroparasites (helminths and arthropods; Peterson 2007). Microparasitic infections that could potentially cause population decline in quails include avian pox and avian malaria (Peterson 2007). Avian pox (*Avipoxvirus spp.*) cases have been reported for northern bobwhite in the southeastern U.S. (Davidson et al. 1982), scaled quail in Texas (Wilson and Crawford 1988), and Gambel's quail in Arizona (Blankenship et al. 1966). Avian malaria has been documented in northern bobwhite in Colorado (Stabler and Kitzmiller 1976); California quail (O'Roke 1930), scaled quail, and Gambel's quail in New Mexico (Campbell and Lee 1953); scaled and Gambel's quail in Arizona (Wood and Herman 1943; Hungerford 1955); and Gambel's quail in Nevada (Gullion 1957). O'Roke (1930) observed California quail infected with avian malaria that were weakened and anorexic, which can lead to death in rare instances, whereas others (Campbell and Lee 1953; Hungerford 1955) noted that malaria is likely not a significant disease for Gambel's quail.

11.6.2 Macroparasites

Helminths are well documented in northern bobwhite and scaled quail. However, information is limited for other species possibly due to the lack of helminth presence in arid and semiarid conditions such as occur in the western U.S. (Moore et al. 1989). Of the helminth species documented, some cause morbidity and mortality in pen-raised quail and potentially wild quails, but their impact on wild quail populations is unknown. *Dispharynx nasuta*, a nematode inhabiting the proventriculus, can cause mortality in chicks of pen-raised northern bobwhite (Kellogg and Prestwood 1968) and has been reported in wild northern bobwhite, California quail, and Gambel's quail in the western U.S. (Table 11.3). Perhaps the most cited example of helminth population regulation in Galliformes is the cecal worm (*Trichostrongulus tenuis*) in red grouse (*Lagopus lagopus scoticus*; Hudson et al. 1998), which causes internal inflammation and bleeding in the ceca of grouse that can decrease grouse survival. The larvae of *T. tenuis* typically favor mesic habitats so its occurrence in western quails is relatively low. Moore et al. (1988) found *T. tenuis* occurring in mountain quail in Oregon that inhabited high-elevation mesic areas (Table 11.3). The cecal worm *T. cramae* is more commonly found in northern bobwhite in Texas (Demarais et al. 1987; Purvis et al. 1998) and is not known to be pathogenic, that is, able to cause disease (Freehling and Moore 1993).

Research from Texas has identified two helminths as potentially pathogenic: the eyeworm (*Oxyspirura petrowi*) and the cecal worm (*Aulonocephalus pennula*). The eyeworm was first reported in Texas in scaled quail and northern bobwhite in the Rolling Plains ecoregion (Table 11.3) and has been a central topic of study in the

Table 11.3 Literature review for four helminth species occurring in quails inhabiting rangelands of western United States

Parasite	Host	State	First reported	Highest reported prevalence	Prevalence *N* (%)
Aulnocephalus pennula	Bobwhite	TX	Webster and Addis (1945)	Dunham et al. 2017	123 (99.2)[a]
	Gambel's	NV	Gullion (1957)	Gullion (1957)	110 (24.0)
	Scaled	AZ	Canavan (1929)	Canavan (1929)	–
	Scaled	NM	Campbell and Lee (1953)	Campbell and Lee (1953)	–
	Scaled	TX	Canavan (1929)	Howard 1981	240 (100.0)
Dispharynx nasuta	Bobwhite	TX	Purvis et al. (1998)	Purvis et al. (1998)	5 (62.0)
	California	OR	Moore et al. (1989)	Moore et al. (1989)	80 (38.0)
	Gambel's	AZ	Gorsuch (1934)	Gorsuch (1934)	–
Oxyspirura petrowi	Bobwhite	TX	Jackson and Greene (1965)	Dunham et al. 2017	125 (95.2)[a]
	Gambel's	AZ	Dunham and Kendall (2017)	Dunham and Kendall (2017)	59 (1.7)
	Montezuma	TX	Pence (1975)	Pence (1975)	3 (67.0)
	Scaled	NM	Dunham and Kendall (2017)	Dunham and Kendall (2017)	53 (28.3)
	Scaled	TX	Wallmo (1956)	Dunham et al. 2017	33 (72.7)[b]
Trichostrongulus tenuis	Mountain	OR	Moore et al. (1989)	Moore et al. (1989)	2 (100.0)

past decade (Bruno et al. 2015; Dunham et al. 2016a, b; Kalyanasundaram et al. 2019; Henry et al. 2020). Concern about the eyeworm arose with the identification of a higher prevalence (95%; Dunham et al. 2016a) and a greater intensity of infection (i.e., 90–100 individuals) in northern bobwhite in the Rolling Plains of Texas than previously reported (30 individuals, Jackson and Greene 1965). Surveys have reported eye worms in scaled quail (Wallmo 1956; Dancak et al. 1982; Landgrebe et al. 2007; Fedynich et al. 2019), Gambel's quail (Dunham and Kendall 2017), and Montezuma quail (Pence 1975) in western Texas, although in lower intensities of infection (Table 11.3).

The cecal worm has garnered similar attention for its high prevalence and intensity of infection. Over 500 worms in an individual host have been reported from northern bobwhite (Dunham et al. 2016a; Bruno et al. 2018) and scaled quail (Fedynich et al. 2019) from Texas. The cecal worm is free floating and does not appear to attach to the cecal wall; however, a disruption in regular feed intake or digestion could negatively impact the host, particularly during times of increased stress. Cecal worms have been reported in scaled quail and Gambel's quail from Nevada and Arizona, but in lower prevalence and intensities (Table 11.3).

11.7 Ecosystem Threats

11.7.1 Habitat Loss

Habitat loss and fragmentation are considered leading causes of global declines and extinctions of species, and these factors also threaten quails on western rangelands (Brennan 1991; Church et al. 1993; Hernández et al. 2013). Habitat loss for quails can occur in at least two forms: (1) actual habitat loss due to factors such as urbanization where the total amount of habitat is reduced and (2) habitat loss via degradation of rangelands due to factors such as establishment of nonnative grasses where the total amount of habitat may remain the same, but the suitability in portions of the existing habitat declines. Habitat loss due to degradation may involve processes such as establishment of nonnative grasses, encroachment of woody plants, and overgrazing and often is amendable by management, albeit sometimes costly. Here we focus on habitat loss due to degradation, the second type.

Quail populations decline when components of important vegetation communities are altered or degraded. The endangered masked bobwhite is thought to have been extirpated in Arizona because of overgrazing by livestock and the accompanying invasion of shrubs (Engel-Wilson and Kuvlesky 2002). California quail and Montezuma quail declines also have been attributed to habitat loss due to overgrazing of herbaceous cover on rangelands and forested savannas, respectively (Brennan 1994). Brennan (1994) believed that intensive agriculture and the construction of hydroelectric reservoirs in the region where the Snake River and Columbia River meet (southeastern Washington, northwestern Idaho, northeastern Oregon), along with overgrazing of secondary riparian corridors, reduced important habitat for mountain quail sufficiently to cause population declines. Even northern bobwhite, which have broader habitat requirements than most other western quails, have experienced significant population declines due to habitat loss in the form of the proliferation of clean farming practices, high-density pine silviculture, and forest succession in the southeastern U.S. (Brennan 1991, 1994).

11.7.2 Invasive Species

Nonnative grass invasions have become a significant form of habitat loss for western quails. Grasses such as coastal Bermuda grass (*Cynodon dactylon*), buffelgrass (*Cenchrus ciliaris*), yellow bluestem (*Bothriochloa ischaemum*), Lehmann lovegrass (*Eragrostis lehmanniana*), and cheatgrass (*Bromus tectorum*) are all nonnative grass species that were introduced either intentionally or unintentionally to native-plant communities in western rangelands. The significance of nonnative grass invasions for quails is that they degrade quail habitat and negatively impact their abundance (Kuvlesky et al. 2012). Nonnative grasses can form dense monocultures that result in reduced forb diversity, grass diversity, arthropod abundance, and bare ground, thereby negatively impacting quail foraging, movements, and space use (Fulbright et al. 2019). Quail abundance therefore tends to be higher in rangelands dominated by native grasses, which provide higher quality habitat than nonnative grasses. For example, northern bobwhite were twice as abundant on areas dominated by native grass compared to areas dominated by buffelgrass or Lehmann lovegrass in southern Texas (Flanders et al. 2006). DeMaso and Dillard (2007) believed that the disappearance of northern bobwhite from the Cross Timbers and Prairies, Post Oak Savanna, and Blackland Prairie ecoregions of Texas partly could be attributed to the introduction and accompanying invasions of coastal Bermudagrass to tens of thousands of hectares. Additionally, Fulbright et al. (2019) reported that scaled quail avoided areas dominated by nonnative grasses and concluded that nonnative grasses could be responsible for declines in scaled-quail populations in southern Texas.

However, nonnative invasive grasses can be of use for quails in certain situations. Kuvlesky et al. (2012) noted that nonnative grasses provide quails with important escape, thermal, nesting, and brood cover, particularly in vegetation communities where these cover types are limited. They noted that the endangered masked bobwhite in Sonora, Mexico likely would not have persisted on the grazed rangelands of this state without buffelgrass, which provided essentially the only cover available to the subspecies. In Texas, northern bobwhite nest in buffelgrass (Buelow 2009; Sands et al. 2012) and use guineagrass (*Urochloa maxima*), another nonnative species, as loafing cover (Moore 2010). Nonnative grasses also do not appear to negatively impact Gambel's quail in Arizona given adequate shrub cover and bare ground (King 1998), and introduced California quail that were successfully established in Washington heavily relied on nonnative plants for food and cover (Crawford 1993). The impact that nonnative grasses have on quails likely depends on the species' life history and the degree by which the nonnative grass has established dominance in an area. For northern bobwhite, the threshold beyond which nonnative grasses such as buffelgrass and Lehmann lovegrass begin to negatively impact their habitat use appears to be ≥ 20% cover (Edwards 2019).

11.7.3 Climate Change

Climate models project that the Southwest and Central Plains of the U.S. will become drier during the twenty-first century, a transition that already appears underway (Archer and Predick 2008; Cook et al. 2015). These regions are projected to experience warmer temperatures and higher frequency of extreme weather events (e.g., droughts, heat waves, and floods; Archer and Predick 2008). For both the Southwest and Central Plains, the risk of multidecadal drought is expected to increase from < 12% (1950–2000) to ≥ 80% (2050–2099), a level of aridity that exceeds even the persistent megadroughts of the Medieval era (1100–1300 CE) (Cook et al. 2015). This projected change in climate may negatively impact western quails, particularly those species inhabiting semiarid and arid environments. The primary impacts likely will involve how quails respond to increasing temperatures and aridity, as well as accompanying distributional and compositional changes in vegetation communities resulting from climate change and projected increases in wildfire frequency (Heidari et al. 2021).

Quails inhabiting arid and semiarid environments live near their physiological limits. For example, the thermal neutral zone for northern bobwhite is estimated at 30–35 °C (Lustick et al. 1972; Forrester et al. 1998), with gular flutter occurring at 35.0–38.5 °C (Case and Robel 1974) and death at 40 °C if individuals are exposed to this temperature for a prolonged period of time (Case and Robel 1974). The thermal environment therefore strongly influences quail life history and ecology, and minor changes in climate can substantially influence their performance (Guthery et al. 2000; Burger et al. 2017). High temperatures are known to cause embryonic mortality (Reyna and Burggren 2012), reduce food intake (Case and Robel 1974), reduce egg laying (Case and Robel 1974), decrease productivity (Heffelfinger et al. 1999), and shorten the nesting season (Guthery et al. 1988). Quails can partly minimize the risk of thermal stress via modifications in space use. For example, northern bobwhite and scaled quail in Oklahoma and New Mexico nest in sites with temperatures that are 6–8 °C cooler than the available landscape (Carroll et al. 2018; Kauffman et al. 2021). However, such behavioral adjustments depend on the availability of thermally suitable sites, which can be limited even in the present climate (Kline et al. 2019; Palmer et al. 2021). The proportion of thermally suitable areas on a landscape may be as little as 40–60% during the hottest time of the day (Forrester et al. 1998) and may become even more limited in the future.

In addition to demographic responses of quails to climate change, quails also can respond by adjusting their geographic distribution because of compositional or distributional changes in vegetation communities. The National Audubon Society used their large-scale, bird-observation database and climate models to project how climate change may affect the geographic distributions of birds (www.audubon.org/climate/survivalbydegrees). Assuming a 3 °C increase in temperature as projected by climate models, 1 quail species is considered to possess high vulnerability (Montezuma quail), 1 moderate vulnerability (scaled quail), 2 low vulnerability (California quail and mountain quail), and 2 stable (northern bobwhite and Gambel's quail) relative to changes in their respective geographic distribution (Table 11.4). These projections agree in general with those of Tanner et al. (2017) who modeled changes in geographic distribution of western quails using an ensemble approach of four general circulation models. They documented that 4 of the 6 species (scaled quail, California quail, Montezuma quail, and mountain quail) are projected to have a net loss in area of geographic distribution. The geographic distributions of Montezuma quail and mountain quail are projected to shift higher in elevation as potential distribution contractions occur in lower latitudes and gains occur in higher latitudes. The net change in the geographic distribution of northern bobwhite is projected to be minimal; however, the species is projected to lose population strongholds. Gambel's quail is the only species projected to experience an increase in area of geographic distribution. Collectively, the geographic distributions of western quails are projected to be displaced northward and eastward, with losses in their southernmost extents (Tanner et al. 2017).

Table 11.4 Projected changes in the geographic distribution of western quails as reported by the National Audubon Society (www.audubon.org/climate/survivalbydegrees) based on a 3 °C increase in temperature

Common name	Species vulnerability	Geographic distribution gained (%)	Geographic distribution maintained (%)	Geographic distribution lost (%)
Northern bobwhite	Stable	37	90	11
Scaled quail	Moderate	28	72	28
Gambel's quail	Stable	56	92	8
California quail	Low	49	57	43
Montezuma quail	High	6	26	74
Mountain quail	Low	56	52	48

11.8 Conservation and Management Actions

The rangelands that western quails inhabit represent a mix of ownerships including federal government, state governments, local municipalities, tribes, corporations, and private individuals (USGS GAP 2018). The differing management authorities among these entities can create a disconnect in conservation objectives for quails. Additionally, wildlife species do not recognize jurisdictional boundaries, further complicating management of western quails. Collaborative efforts among these managing entities have had, and will continue to have, the greatest potential for quail conservation and management in western rangelands.

11.8.1 Conservation Programs for Public Rangelands

The federal government manages a substantial proportion of western lands, and some federal agencies operate under directives to manage lands for multiple uses including the provision of fish and wildlife habitat (Vincent et al. 2020). It is estimated that the Bureau of Land Management (BLM) alone contains more than 8.1 million hectares of quail habitat: 4.9 million hectares (Gambel's quail), 1.6 million hectares (scaled quail), 1.2 million hectares (California quail), 1.1 million acres (mountain quail), 0.5 million hectares (northern bobwhite), and 110,000 ha (Montezuma quail; Sands et al. 1992). This large holding of quail habitat represents great potential for management and opportunities for federal and state agency collaboration on quail management and conservation. The Sikes Act of 1974 (Public Law 93-452) provides one avenue for collaborative funding for wildlife habitat on federal lands by requiring people who hunt, fish, or trap on certain federal lands to purchase a stamp that provides funding for the conservation and restoration of these lands (Public Law 93-452). New Mexico created the Habitat Stamp Program in 1986 under the federal Sikes Act and since then has raised more than \$26 million dollars and completed more than 2000 projects, some of which have benefitted quails (NMDGF 2017).

In addition to routine habitat management on federal lands within the geographic distributions of quails, federal agencies also are able to create initiatives aimed at specific species or habitats. "Answer the Call" was one such initiative directed at managing habitats for quails on federal lands. Started in 1988 as part of the U.S. Forest Service's (USFS) Get Wild program, "Answer the Call" was directed to make improvements to quail habitat on National Forest System lands (USDA 1991). The USFS collaborated with Quail Unlimited (a former non-government organization), BLM, and National Fish and Wildlife Foundation to implement this program and improve over 80,000 hectares of quail and associated wildlife habitat on National Forests across the U.S. (USDA 2004). "Answer the Call" is still available through the USFS but Quail Unlimited disbanded in 2013 thereby slowing the implementation of the program.

11.8.2 Conservation Programs for Private Rangelands

Despite the fact that a smaller proportion of western rangelands is privately owned (Vincent et al. 2020), private lands have conservation value for western quails. Much of rural, private land is used for agricultural purposes (Robertson and Swinton 2005), and land-use decisions generally are made by landowners to support their livelihoods and families (Heard 2000). Such heavy reliance of these private rangelands on agricultural use has earned them the name of "working lands" (i.e., privately owned land in agricultural production) (Naugle et al. 2020).

Conservation of wildlife species on working lands, specifically grassland birds such as quails, can be achieved through voluntary conservation efforts by private landowners that are supported by strong partnerships between landowners and resource professionals (Drum et al. 2015). Conservation programs or initiatives for private lands must consider socioeconomic factors and how they impact landowner decisions-making (Drum et al. 2015). Conservation practices that are cost-effective, sustainable, and compatible with agricultural systems are often attractive to landowners (Burger et al. 2006, 2019). For example, private landowners in Texas placed great importance on minimizing out-of-pocket costs and labor input when making decisions about whether and how to restore northern bobwhite habitat (Valdez et al. 2019).

The 1985 Food Security Act (Farm Bill) is "an omnibus, multiyear law that governs an array of agricultural and food programs", including conservation incentive programs (Stubbs 2019). The U.S. Farm Bill provides private landowners cost-share payments for implementing United States Department of Agriculture (USDA) conservation practices (Briske et al. 2017). Thus, Farm Bill programs are a primary vehicle for implementing quail conservation on private lands (Burger et al. 2006), and the primary land conservation program of the Farm Bill is the Conservation Reserve Program (CRP).

The Conservation Reserve Program provides compensation to private landowners who voluntarily remove lands from agricultural production to improve soil and water quality (Stubbs 2019). The initial impact of CRP on quails has varied by region and method of implementation (Burger 2006). In the Midwest, CRP lands planted to native grasses were extremely beneficial to quails, but CRP lands planted to nonnative grasses or enrolled in tree planting practices produced minimal benefits for quails (Burger 2000, 2006). In addition, the disturbance frequency and intensity of mid-contract management that CRP requires may not provide the level of disturbance needed to create the greater habitat heterogeneity that species such as the northern bobwhite require (Pavlacky et al. 2021). However, the Continuous CRP provides an option to create a more species-directed approach to the program and, in 2004, a new continuous CRP practice (CP33–Habitat Buffers for Upland Birds) was announced (Burger et al. 2006). In these 10-year contracts, field buffers are planted with native grass, forb, and shrub mixes, or re-established through natural succession (USDA FSA 2010) and followed up with site disturbance (mid-contract management) to maintain early successional habitat (Burger et al. 2006). The CP33 practice has provided habitat for quails while compensating landowners for removing hard-to-farm lands from production (Burger et al. 2006).

The two largest working lands programs of the Farm Bill are the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP; Stubbs 2019). These programs financially incentivize landowners to adopt conservation practices on their privately owned lands (Burger et al. 2019), and research indicates that northern bobwhite have responded positively to buffers, creation of early succession habitat, and restoration of native grasslands when managed to maintain appropriate vegetative structure (USDA NRCS 2009).

Another important collaborative program created by the 2014 Farm Bill is the Regional Conservation Partnership Program (RCPP) whereby conservation partners select an area of concern, determine conservations goals, and implement conservation practices using funding provided by Farm Bill and partners (Stubbs 2019). The RCPP has potential for large-scale conservation of western quail habitat. For example, the Oaks and Prairies Joint Venture received RCPP funding to implement its Grassland Restoration Incentive Program in Texas and Oklahoma that has potential to positively impact northern bobwhite (NBCI 2018).

Factors that may limit the effectiveness of Farm Bill conservation efforts on private lands are the lack of documented outcomes and staff capacity at USDA offices. Briske et al. (2017) concluded that the existing conservation practice standards are insufficient to conserve rangelands at a large scale and recommends that USDA-NRCS modify conservation programs to incorporate evidence-based conservation, including collaborative monitoring of conservation practices to understand environmental outcomes. To address the staff capacity issue, local, state, private, and federal partners have created partner biologist positions to provide technical assistance and work with private landowners to promote USDA conservation programs (PLJV 2019). These partner positions often work in local USDA service centers and provide technical and financial assistance to private landowners for habitat improvements (PLJV 2019). The non-government organization Pheasants Forever/Quail Forever has created 188 positions in 30 states to maximize implementation of USDA conservation programs (Burger et al. 2019), thereby indicating that non-government organizations will be increasingly important in the future.

11.8.3 Conservation Partnerships

The Association of Fish and Wildlife Agencies (AFWA) and their regional affiliates (WAFWA, MAFWA, SEAFWA, NEAFWA) agencies have been critical in facilitating meetings among wildlife managers, funding collaborative efforts, and providing staff to assist in multijurisdictional management. As conservation issues arise, the associations create working groups or technical committees comprised of state biologists or other wildlife professionals. The development of such groups provides collaborative opportunities for biologists working throughout the geographic distributions of quails.

11.8.3.1 National Bobwhite Conservation Initiative

During 1980–1999, northern bobwhite populations declined by an estimated 65.8% across their geographic distribution (Dimmick et al. 2002). This decline led the Southeast Association of Fish and Wildlife Agencies to task the Southeast Quail Study Group with creating a plan for the recovery of northern bobwhite (Dimmick et al. 2002) resulting in the National Bobwhite Conservation Initiative (NBCI) in 2002 (Dimmick et al. 2002). The NBCI was the first collaborative effort to create a range-wide management plan for northern bobwhite (NBTC 2011), and the NBCI now partners with a variety of federal, non-governmental, and academic organizations to carry out its mission.

11.8.3.2 Western Quail Working Group

Following the successes from the NBCI, the Resident Game Bird Working Group of the AFWA directed the creation of the Western Quail Management Plan (Zornes and Bishop 2009). This plan was a collaborative effort of biologists across the West to compile and evaluate information on western quails at both their geographic distributions and individual Bird Conservation Regions (BCR). Information provided for each BCR included population size, habitat abundance, current threats, management recommendations, and research needs. Following the finalization of the Western Quail Management Plan in 2009, the WAFWA signed a memorandum of understanding to create the Western Quail Working Group (WQWG; WAFWA 2011) and help foster cooperation across state lines to effectively manage species at regional scales (WAFWA 2011).

11.8.3.3 Joint Ventures

Bird Habitat Joint Ventures were established in the late-1980s to provide coordinated conservation planning for migratory birds at regional scales (USFWS 2005). There are currently 18 Bird Habitat Joint Ventures that encompass most of the U.S. and are comprised of self-directed partnerships between government and non-government organizations, corporations, and private individuals (Faaborg et al. 2010; Giocomo et al. 2012). Joint Venture administrative boundaries are primarily defined by Bird Conservation Regions boundaries (Giocomo et al. 2012). Given that both the NBCI and Western Quail Management Plan delineate quail management objectives by Bird Conservation Regions, Joint Ventures are well positioned to aid in quail conservation efforts. Since their inception, Joint Ventures have facilitated collaboration among > 5700 partners and assisted in habitat conservation on 10.9 million acres (USFWS 2018). Although created to focus on migratory birds, many regional Joint Ventures include non-migratory species such as northern bobwhite as priority species. In 2017, 7 of the 12 Joint Ventures that occur within the geographic distribution of northern bobwhite listed it as a priority species (DeMaso 2017).

11.9 Research Needs

Although game species tend to be well studied, the dynamic nature of western rangelands and the increasing human footprint create a perennial need to address emerging issues. We provide general research and management priorities for quails as a taxon and at the scale of their geographic distributions. From a demographic perspective, the need exists to quantify the cumulative impact of climate change, landscape alterations (e.g., habitat loss and fragmentation, non-native grasses, large wildfires), and demographic processes (e.g., dispersal, predation, disease) on quail-population viability. Investigations on population genetics of quails also are necessary to develop a more thorough understanding of genetic relatedness, taxonomy, and evolutionary history of quails to aid in their conservation efforts. From a management perspective, research on quail response to rangeland-management practices is limited in scope (1–2 species) and geographic extent (mostly Texas, Oklahoma, and New Mexico) and warrants investigation. In addition, the need exists to develop effective management strategies for invasive, nonnative grasses. Reliable monitoring techniques also are needed for quails that can be applied at both small and large spatial extents, especially for species such as Montezuma quail and mountain quail that have low detection probabilities. In recent years, the translocation of wild quails to restore declining populations of western quails has received research attention (Troy et al. 2013; Downey et al. 2017; Ruzicka et al. 2017) but warrants further evaluation to determine the viability of the technique as an effective conservation tool.

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