POST-FIRE SUCCESSION AND MONTEZUMA QUAIL IN A SEMI-DESERT GRASSLAND OF SOUTHEAST ARIZONA

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ABSTRACT

A 1,011.7-ha wildfire occurred in southeast Arizona in May 2009 and provided an opportunity to evaluate pre- and post-fire abundance of and habitat use by Montezuma quail (*Cyrtonyx montezumae*) through use of flush surveys and radiotelemetry. We evaluated movements of radio-marked quail from 2 months prior to the burn to 12 months post-burn. We observed strong site fidelity with coveys persisting in small patches of unburned areas and micro-topography, despite extensive reduction in cover in the surrounding landscape. We documented 46.7% reduction in abundance using flush counts within the first 2 weeks post-fire, and 66.7% reduction within 3 weeks post-fire. We also documented roosting within a fire-affected area and successful nesting by Montezuma quail a few months following a wildfire.

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INTRODUCTION

Opportunities for studying the impact of natural wildfires on vertebrate populations are limited in wildlife field studies. There is substantial scientific literature on how wildlife populations respond to post-fire conditions but few studies evaluate those impacts for species that have been marked and radiotracked before a fire occurs (Bond et al. 2002, Cram et al. 2002, Craig et al. 2010, Martin et al. 2010). Experiments using controlled burns have evaluated how some North American quail respond to fire (Renwald et al. 1978, Wilson and Crawford 1979, Ransom and Schulz 2007), but more can be inferred from how wild vertebrate populations respond to fire when an event is stochastic with the range and intensity of a fire varying naturally rather than manipulated experimentally. This is especially true for protected species, species of conservation concern (e.g., masked bobwhite [*Colinus virginianus ridgwayi*]), or those with limited distribution or narrow habitat requirements (e.g., Montezuma quail) where controlled burns may not be permitted or feasible.

Fire is a naturally occurring phenomenon in the semi-desert grasslands of Arizona and has potential to severely reduce available ground cover upon which scaled quail (*Callipepla squamata*) and Montezuma quail are dependent for use in escaping danger, providing shelter and insulation from ambient climate conditions, and nesting (Leopold and McCabe 1957, Brown 1979, Guthery et al. 2001, Bristow and Ockenfels 2004, White et al. 2011). The effect of fire at the population level for Montezuma quail is a priority management issue for conservation of this species (Arizona Partners in Flight 1999). Past difficulties in adapting adequate methods for studying wild Montezuma quail (Hernández et al. 2009) have led to knowledge gaps about this species. Some observations on the relative abundance of Montezuma quail post-fire have been reported (Bock and Bock 1978), but methods used lacked accuracy compared to flush-counts conducted with

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dogs or by tracking marked quail with radiotelemetry. Few studies have been successful in monitoring movements and survival of Montezuma quail with radiotelemetry (Stromberg 1990), but recent adaptations of traditional methods have allowed tracking populations with greater success.

The Canelo fire was a human-caused incident that impacted some areas of the Appleton-Whittell Research Ranch (AWRR) where research on Montezuma quail was conducted prior to the burn. The fire's point of origin was outside AWRR at ~ 31° 55′ N, 110° 51′ W. It was reported to have started on 5 May 2009 at 1300 hrs and was contained and controlled by 9 May 2009 at 1800 hrs. It qualified as fire intensity level 5 and burned 1,702.9 ha, of which 1,011.7 were within the south and eastern parts of AWRR. The wildfire provided an opportunity to examine its impact on resident quail that had been radiomarked and their population abundance monitored via pointing-dog flush-counts. Our objective was to evaluate abundance, behavior, and habitat use of Montezuma quail from 2 months prior to and 12 months after the wildfire.

STUDY AREA

We monitored Montezuma quail at AWRR near Elgin, Arizona (~ 31° 35′ N, 110° 30′ W) and in the Coronado National Forest, administrated by the U.S. Forest Service (USFS), which directly bordered the boundaries of AWRR. The Research Ranch encompasses ~ 3,237 ha in the western foothills of the Huachuca Mountains at an elevation of 1,417-1,570 m. AWRR is designated as a sanctuary and is owned and managed by the National Audubon Society. Livestock grazing is not permitted and hunting of game species is prohibited.

The dominant vegetation at AWRR consists of species common to Plains and Great Basin grasslands, including perennial grama grasses such as sideoats grama (*Bouteloua curtipendula*), hairy grama (*B. hirsuta*), and indigenous plains lovegrass (*Eragrostis intermedia*). Sacaton (*Sporobolus wrightii*) grasslands are well-represented along the bottomlands of Turkey Creek. Drainages and nearby riparian habitat are dotted with sycamore (*Platanus wrightii*), willows (*Salix* spp.), and cottonwood (*Populus fremontii*). Madrean Evergreen Woodlands, dominated by Emory oak (*Quercus emoryi*) and Arizona white oak (*Q. arizonica*) are sparsely dispersed among the sloping hills of the Ranch but are generally found in greater densities along AWRR's southern and eastern borders in the adjacent Coronado National Forest. McLaughlin et al. (2001) noted grass species are most abundant on AWRR with < 3% succulents (Cactaceae, Agavaceae, Nolinaceae) and < 15% woody species.

Large wildfires (> 10 ha) have been infrequent at AWRR within the past 20 years because of suppression efforts. Limited prescribed burns have been conducted to study the effects of fire on ungrazed semi-desert grasslands in Arizona (Bock and Bock 1992b), including its impact on two exotic African grass species, Lehmann lovegrass (*E. lehmanniana*) and Boer lovegrass (*E. curvula*), which have persisted since the 1940's (Bock and Bock 1992c). Plans to integrate prescribed burning as a method for restoring natural fire frequency and native ecosystem processes have been superseded by the occurrence of recent fires including the Ryan Wildfire on 30 April 2002 which burned 2,913.75 ha within AWRR. The general species composition of AWRR has not changed in response to recent fires with exception of non-native grasses which have persisted and tend to colonize rapidly immediately following a burn (Bock and Bock 1992c).

We studied the northern and northeastern boundaries of the area affected by the Canelo fire within the AWRR boundary and defined this region into 4 zones (Fig. 1). Zone A was not affected by the fire (0% burn), part of zone B burned (~ 50% burned), most of zone C burned (> 80% burned), and most of zone D burned (> 95%). Fire suppression effort within AWRR was greater near the housing (zone C) and administrative structures (zone B), which were not affected by the fire. Zone A was largely dominated by native bunchgrasses with interspersed oak trees lining the washes, but was the area where exotic lovegrass species were highest in abundance. Zones B and C had greater representation of sacaton within the bottomlands and contained sycamores, willows, oaks, and mesquite. Zone D had high abundance of sacaton in the bottomlands but greater representation of native grasses, agave, yucca, and oaks along the ridges.

METHODS

We initially used trained pointing dogs to locate Montezuma quail (Brown 1976) at AWRR during surveys conducted between 0500 and 1700 hrs from February 2009 to July 2010. Daytime flush counts using dogs (Brown 1976) served as the most practical means of obtaining population estimates of this species. Quail flush points from daytime surveys were georeferenced using Universal Transverse Mercator (UTM) coordinates in NAD83 datum and were used to locate possible roosts for trapping at night. Surveys with trained dogs were conducted from ~ 1900 to 0300 hrs and served as the primary means of locating and trapping unmarked quail with large hoop-nets in unburned areas (Brown 1975). Efficiency of night-trapping was, at times, facilitated through use of a Forward-looking Infrared (FLIR) camera which was used to narrow the probable location of a covey from thermal signatures detected by the camera. Standard wire-cage funnel traps baited with seed and, at times with a taxidermy quail mount as a lure, were also used to capture quail.

Captured birds were marked with aluminum leg bands and backpack radio transmitters (~ 5–8 g, < 5% of body mass; Wildlife Materials, Murphysboro, IL, USA) using enhanced methods adapted from Stromberg (1990) and Hernández et al. (2009). Morphological characteristics of captured quail (i.e., gender, age, body condition, wing length) were recorded and birds were released before dawn. Radiotelemetry was used to locate unmarked birds within a covey for capture once several

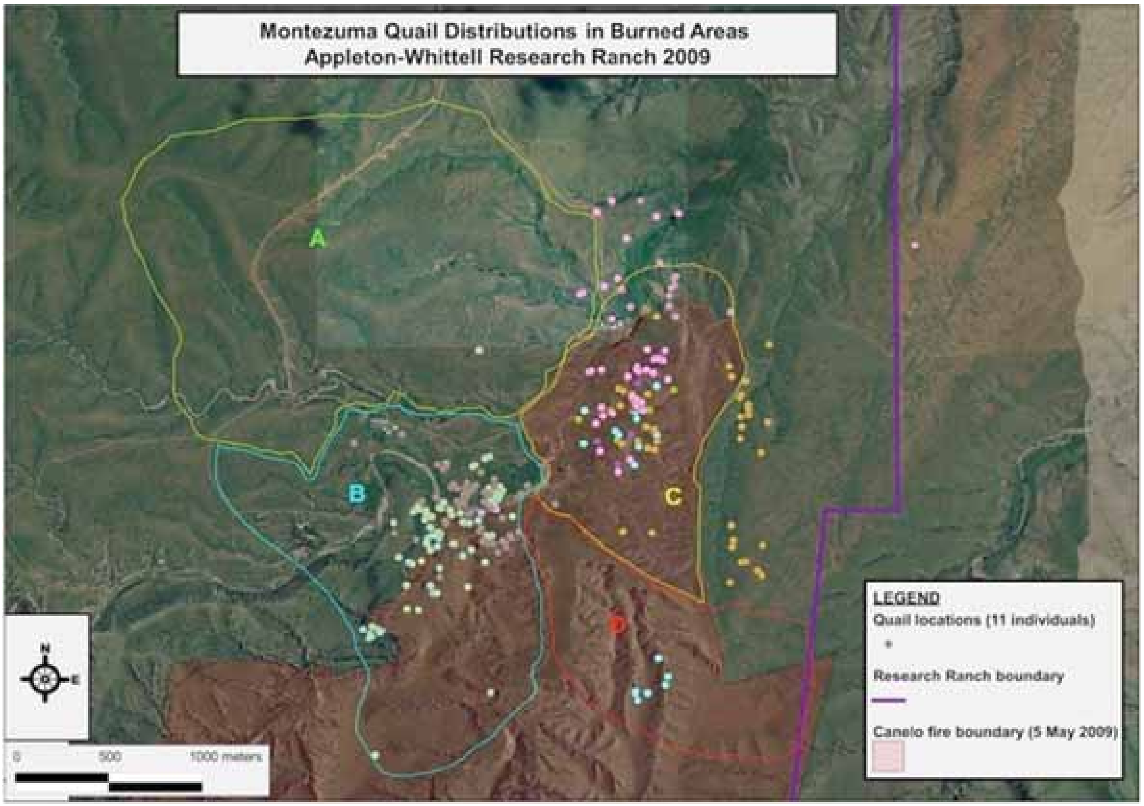

Fig. 1. Distribution of radio-marked Montezuma quail using burned areas in 2009 on the Appleton-Whittell Research Ranch following the Canelo fire (5 May 2009). Surveys conducted in zones A–D ranged from February to October 2009.

birds in a covey were radiomarked. Radio-marked birds were monitored 2–5 times a week during random hours stratified by day (0700–1900 hrs), when quail were most active, or night (1901–0659 hrs), when quail were primarily roosting.

Flush counts with dogs were periodically conducted, ~ 2–4 times a month, during the day to record changes in covey size and gender demographics throughout zones A–D at AWRR (Fig. 1). Flush-count surveys with pointing dogs in zones A and B were conducted from February to May, followed by initial trapping efforts. Surveys in zone C began in early April and monitoring at zone D began once quail were reported by AWRR biologists post-fire. The frequency of flush counts conducted per month, for both 2009 and 2010, was greater when surveying during November–April when research activities would have less impact on pair formation, breeding, and nesting which occur from May to October. Abundance of quail in each zone was calculated as the sum of those radiomarked in each zone plus those not marked and flushed with dogs. Estimates of abundance from flush counts using dogs within each zone were evaluated 2 weeks pre-fire and 2 weeks post-fire for up to 3 weeks.

Flush counts using dogs potentially posed a greater risk to quail survival due to reduction in available escape cover, and we used radiotelemetry as the primary method to monitor covey size and abundance in burned areas. Habitat use, home range, and topography were recorded for radio-marked quail. Roost and nest sites were also georeferenced and compared between burned and unburned areas for each individual. We evaluated quail movements in burn and unburned areas using Quantum GIS (QGIS) 1.7.0 (QGIS 2011) including only movements after 5 May 2009. We recorded locations where quail were observed within the burned area for each individual to estimate use of burned habitats. Preliminary analysis of home range-size was assessed using 25, 50, and 95% fixed kernel range estimates, or utilization distributions (Worton 1989), derived with the Home Range Extension in ArcView 3.2a (ESRI 2000). Survival of radio-marked birds using the burned areas, along with their status at last location (i.e., cause of mortality) was evaluated from the week the burn occurred to October 2009.

RESULTS

We estimated the pre- and post-fire population in zones A+B, C, and D at 2 weeks pre-, 2 weeks post-, and 3 weeks post-fire (Table 1). These estimates included quail reported by AWRR biologists (Table 1). We observed a 35.3% decrease in abundance within 2 weeks post-fire in zones A+B. We observed a 46.7% decrease in abundance within 2 weeks post-fire in zone C. We had no records of radio-marked or flushed birds in zone D 2 weeks before the fire, but observed 1 covey of 5 birds there 2 weeks post-fire. We believed the covey in zone D was different from coveys previously observed in zones

Table 1. Abundance of Montezuma quail up to 3 weeks post-fire estimated from pointing dog flush-counts, including number of quail radiomarked within the population, at Appleton-Whittell Research Ranch, Elgin, Arizona. Zones A–D correspond to regions surveyed within AWRR: A (0% burned), B (∼ 50% burned), C (> 80% burned), and D (> 95% burned). Unk = unknown.

	Zones A + B			Zone C			Zone D	
Montezuma quail	2 weeks pre-fire	2 weeks post-fire	3 weeks post-fire	2 weeks pre-fire	2 weeks post-fire	3 weeks post-fire	2 weeks post-fire	3 weeks post-fire
# Radiomarked	9	5	9	2	0	2	0	0
# Flushed by dogs	25	17	16	28	16	8	5	0
# Reported by staff	5–7	5–7	5–7	unk	unk	unk	4–6	unk
Estimated totals	34	22	25	30	16	10	5	0

A+B or C. We estimated a 13.6% increase in abundance of quail in zones A+B from week 2 to week 3 post-fire, but an overall 26.5% reduction in abundance from 2 weeks pre-fire to 3 weeks post-fire (Table 1). We observed a 37.5% decrease from week 2 to week 3 post-fire, but an overall 66.7% reduction in abundance from 2 weeks pre-fire to 3 weeks post-fire in zone C. No quail were observed 3 weeks post-fire in zone D, a 100% reduction in local abundance (Table 1).

Thirty-two Montezuma quail were trapped in 2009 at AWRR of which 15 were tracked after 5 May 2009 and 11 were observed using the burned area (Table 2). One additional bird (female #777) was not radiomarked or banded but relocated from observing her at a nest. Four of the 11 radio-marked birds observed using burned areas originated in coveys from zone B and 7 originated from coveys in zone C. We made few observations prior to the fire of radio-marked birds using areas that would later burn. One juvenile female (#226) in zone B had at least 3 locations within the edge of zone C, 2 weeks prior to the fire. Adult female (#221) was observed with an unmarked male on 3 May in a large sacaton bottomland in zone C that burned within 2 days. The next visual relocation for #221, on 7 May 2009, was 708 m from the burned area in another large sacaton bottom in the unburned northwest edge of zone B.

The number of telemetry relocations for the 11 radio-marked birds in 2009 ranged from 7 to 49 and varied based on when they were initially trapped, how long they were observed before their death, and if transmitter loss or failure prevented further data collection (Table 2). The mean of radiotelemetry relocations in the burn was 60.9% and ranged from 21.4 to 100% (Table 2). Several ($n = 11$) radio-marked Montezuma quail in this study had 50% fixed kernel range core use areas in the burned area and 9 of these also had 25% fixed kernel core use areas within the burn (Table 2). We suspected most depredations were caused by raptors; this included radio-marked quail with the highest number of locations in the burn, females #221 and male #233 (Table 2). We observed several quail (#221) roosting (Table 2) at the edge of the burn in the unburned area, including 1 individual (#233) that roosted within 32 m of the edge of the burn. Some individuals (#226 and #233) did not have any known roosts in the burn. Quail were observed foraging during the day in the burned sacaton bottomlands using the remaining base of sacaton grasses or any nearby fallen debris and snags as cover. All radio-marked birds in zone C roosted within the burn, and roosts detected per individual in the burn, compared to unburned, ranged from 33.3 to 100%. Females attempted to nest in burned areas during vegetation recovery post-burn. Two radio-marked females and 1 unmarked female nested in the burn, while 3 radio-marked females nested in unburned areas. One female (#226) had 2 nest attempts that were within 50 m of the burn edge.

Table 2. Demographics of radio-marked Montezuma quail in 2009 using the burned area following the 5 May 2009 Canelo fire at Appleton-Whittell Research Ranch, Elgin, Arizona. AHY = after hatch year (Adult), HY = hatch year (Juvenile). Core areas in burn represented by 25 and 50% fixed kernel range estimates (Worton 1989) derived from radiotelemetry data.

Band #	Gender	Age	Dates tracked after the fire	# of locations	% locations in burn	# roosts in burn	Nest in burn?	Core areas in burn 25–50%	Condition at last location
221	F	AHY	7 May–9 Jul	33	60.6	1	Unknown	50	Dead; raptor suspect
226	F	HY	7 May–19 Oct	26	38.2	0	0 of 2	50	Lost transmitter
233	M	AHY	26 May–8 Jun	7	85.7	0	Unknown	25–50	Dead; raptor suspect
234	M	HY	26 May–22 Aug	49	49.0	1	Unknown	25–50	Transmitter failed
238	M	HY	19 Jun–16 July	12	100.0	1	Unknown	25–50	Lost transmitter
239	F	AHY	16 Jun–25 Aug	40	70.0	6 of 8	0 of 1	25–50	Transmitter failed
240	F	HY	19 Jun–19 Oct	42	45.2	2 of 6	0 of 1	25–50	Dead; raptor
241	F	HY	19 Jun–20 Aug	20	100.0	2 of 2	1 of 1	25–50	Transmitter failed
242	M	AHY	19 Jun–16 Jul	12	100.0	2 of 4	1 of 1	25–50	Transmitter failed
243	F	AHY	10 July–23 Oct	29	96.6	5 of 5	1 of 1	25–50	Dead, (Jan 2010)
244	F	AHY	1 Aug–19 Oct	14	21.4	1 of 1	0 of 1	25–50	Lost transmitter
777	F	AHY	16 Jul–8 Aug	10		1	1		Not radiomarked
				Average	60.9				

The majority of Montezuma quail in 2010 were observed in zone C. Flush-count surveys with dogs in January 2010 estimated 38–60 Montezuma quail within zone C and possibly 10–15 in zones A+B. One quail (#243) survived from 2009 and was monitored along with 21 previously unmarked individuals in 2010. We obtained 235 locations for 22 radio-marked Montezuma quail from January to April 2010; 206 (93.6%) of 220 locations were within the recovering burned areas in zone C.

DISCUSSION

Montezuma quail abundance within some burned zones remained high despite a marked reduction in available cover (Table 1). Small islands of unburned bunchgrass present in the hills at the northeast edge of the fire (zone C) provided adequate cover to sustain coveys that had been resident throughout the bottomlands that burned. The pre-fire abundance and density of the islands of bunchgrasses which the quail used for cover post-fire, however, were naturally lower, and considered less ideal, in comparison to areas they would typically inhabit. At least 2–3 coveys in zone C before the fire foraged and roosted in high-density grass flats within 10–50 m of the sacaton bottomlands. These grass flats were more vulnerable to fire in comparison to those which persisted in the rough and rocky canyon banks and sandy wash bottoms. Micro-topography, soil type, and rocky substrate provided some protection from fire in some areas of zone C, allowing cover and quail to persist within these unburned pockets. A few pockets of unburned sacaton remained in the more rugged wash bottoms in zone D but which occurred in low densities and widely interspersed throughout the affected area. Quail that remained in zone D were within these remaining small pockets of sacaton. When flushed, these birds took cover at the fire-charred bases of *Agave* spp. or *Nolina* spp., which did not provide adequate cover and are not ideal habitat for Montezuma quail even when unburned.

Quail abundance decreased in burned areas (zones C+D) 2–3 weeks post-fire but did not correspond to increased abundance in unburned areas (zones A+B) when compared to estimates before the fire (Table 1). Flush-counts with dogs confirmed some unmarked quail from zone C moved to the unburned edge across the road into zone A, but their numbers were small ($3 \leq n \leq 8$) in comparison to pre-fire abundances. High mortality of unmarked quail was observed within 2 weeks post-fire in zones A+B, but it is unknown how many of these corresponded specifically to those that may have been from zone C. Mortality rates from direct susceptibility to fire are unknown for most North American quail. Most literature on the impact of fire on quail suggests, but does not provide direct evidence for, low probability of mortality directly from fire due to innate high mobility and the ability of quail to fly. Recent studies, however, show that prescribed-burns have had low direct impact on mortality of bobwhites (Martin et al. 2010). Montezuma quail behavior during a fire has not been documented. Given their adaptation to remain motionless in response to perceived danger, it is intuitive that some may have moved too late and eventually died from fire-related injuries, or were perhaps surrounded by and could not escape the fire. Unfortunately, the high intensity of the fire, which burned many oaks and sycamores below their bases, left little chance of finding any quail carcasses post-fire.

Strong site fidelity in this species has been documented from radiotelemetry studies (Stromberg 1990) but, until now, there has been no evaluation of response to fire or any other large disturbance events. Our observations provide strong evidence for site fidelity in Montezuma quail in burned areas post-fire. Evidence is provided from individuals within coveys that were radiomarked within 1.5–2 months post-fire (Table 2). Site fidelity remained high in burned areas even when there was little to no cover available immediately post-fire. The covey detected in zone D was observed within a severely burned bottomland up to 20 days post-fire.

Feeding activity in a burned area (zone C) was observed within days post-fire with quail taking cover beside large fallen snags of sycamores or by rocks and rough micro-topography along the banks of Turkey Creek wash. Quail were observed scratching, apparently for seed or tubers that remained underneath the ash and hardened soil. The onset of summer monsoons provided rainfall as early as 21 May and moderate precipitation events followed on 28 May and 10 June. Herbaceous vegetation subsequently carpeted burned areas with apparent eruptions of insect populations, especially grasshoppers. Bock and Bock (1991) observed similar trends for grasshoppers at AWRR post-fire. Montezuma quail were observed feeding in burned areas with new vegetation and in areas with higher concentrations of insects.

The earliest active roosts ($n = 2$) directly within a burned area were recorded at 19 and 24 days post-fire, but others were found earlier in islands of unburned grass within or at the edge of the burn. Several active nests were located within the burned area, including 2 that were found 68 days post-fire and 1 that was found 96 days post-fire. The first 2 nests found were in areas with poor cover. Vegetation in the sacaton bottomlands recovered more quickly than in upland areas and, eventually, provided adequate cover where 2 of the nests were located. One nest was on a burned ridge dominated by *Agave* spp. and initially had sufficient cover within the bunchgrass that had recovered at the base of an agave. The landscape surrounding this nest, however, had poor to no recovery of native bunchgrasses and remained very open 3 months post-fire. The female from this nest was observed making movements of > 100 m to feed on forbs and insects that were in greater abundance at the base of the burned hills.

Productivity in burned areas seemed to not be severely affected the following season. Abundance estimates were higher 8 months post-fire in burned sacaton bottomlands than in those that were not burned. This contrasts with observations of Bock and Bock (1978) who noted decreased abundance of Montezuma quail 1 year post-fire. The methods used by Bock and Bock (1978) to survey birds were likely not effective for detecting Montezuma quail.

There is agreement among some biologists that Montezuma quail have 'co-evolved' with grass cover and range fire (Harveson et al. 2007). Thus, populations have recovered in regions where large-scale wildfires have restored native vegetation structure more favorable for their survival (Zornes and Bishop 2009). Montezuma quail may respond differently than other North American quail when exposed to changes in the surrounding landscape brought about by variation in fire intensity, and changes in vegetative structure available for cover. Fire in late spring may impact Montezuma quail breeding behavior and available habitat for nesting. Our research shows that Montezuma quail use burned areas immediately following fire and their resilience includes the ability to roost in burned areas within weeks post-fire and nest within months post-fire when surrounding habitat (e.g., sacaton bottomlands) provide cover during early stages of post-fire succession.

MANAGEMENT IMPLICATIONS

Quail biologists have documented the importance of fire and prescribed burns in conservation and management of North American quail (Cram et al 2002, Brennan and Kuvlesky 2005, Brennan 2007). Our research provides baseline natural history observations of Montezuma quail that are helpful for managers considering implementing prescribed fire in areas where this species is present. Some studies have showed mixed results of application of fire for managing quail populations, particularly in semi-arid grasslands (Ransom and Schulz 2007). Our research indicates fire in open semi-desert grasslands is detrimental to Montezuma quail population recovery for several months post-fire if the surrounding areas do not have nearby unburned sacaton bottomlands for cover.

Fire restructures habitat that can favor nesting of some quail species (Brooker and Rowley 1991) and generally benefits increased abundance of some native grassland birds (Bock and Bock 1992a), especially when exotic vegetation is removed in the process. These aspects have not been explored thoroughly for Montezuma quail and more research is needed concerning site fidelity and movement patterns.

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