Impacts of Wildfire on Wildlife in Arizona: A Synthesis

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***Abstract**—Due to a century of fire suppression practices, the Madrean Archipelago regions in Arizona have accumulated excessive fuel loads that increase wildfire sizes, intensities, and frequencies. Wildfire induced structural changes in forest ecosystems can either benefit or adversely impact wildlife species. Therefore, it is imperative to understand how wildlife species react to such ecosystem changes after wildfires in both the short-term and long-term time periods. We examined scientific literature to determine wildlife distribution, abundance, elevational migration, and behavioral changes (i.e. how wildlife use resources post-fire) in response to wildfire. Understanding the impacts of wildfire-induced habitat fragmentation and creation of edge effects on wildlife species will provide information about overall forest condition and forest management practices.*

Introduction

The Madrean Archipelago stretches from the Mogollon Rim in northern Arizona to the Sierra Madre Occidental in northwestern Mexico (Ffolliott and others 1995; Warshall 1995). The archipelago consists of 40 Sky Islands, which are a series of isolated mountain ranges that contain several vegetative zones that extend upwards from flat, low-lying arid regions (Ffolliott and others 1995; McLaughlin 1995). Sky Islands have geographically isolated species since the last glaciopluvial event and therefore harbor elevated species diversity and richness (Lomolino and others 1989; Warshall 1995). The 19 Sky Island complexes in Arizona provide refuge for the great diversity of mammals, reptiles, and ants (Warshall 1995). However, biodiversity of endemic montane species is negatively impacted by grazing, soil erosion, introduced exotic species, habitat fragmentation and wildfire. Fire suppression practices for over a century have caused an increase in fuel loads that allow wildfires to increase in frequency, intensity, and size (Covington and Moore 1994; Sackett and others 1994; Swetnam 1990). These large, intense fires are rapidly changing ecosystems and these cover type conversions may have adverse impacts on flora and fauna. The occurrence of such large scale, high intensity wildfires is predicted to continue to increase in the region exacerbated by climate change (Westerling and others 2006). Herein, we briefly review the historical pattern of fire and the effects of wildfire on wildlife in Arizona.

Wildfire Impacts

Historical Pattern

Before 1900, low-severity ground fires were common and burned every 2-15 years (Brown and Smith 2000; Kiltie 1989; Swetnam and Baisan 1996b; Thomas and McAlpine 2010). Since fire suppression practices altered the natural fire regime in Arizona, catastrophic stand-replacing wildfires are increasing in frequency and have burned over 1.5 million ha within the last decade (fig. 1; Southwest Coordination Center 2012). Flora and fauna species may not be adapted to these increasingly large and intense wildfires (Swetnam and Baisan 1996b). Fires can create a mosaic of burn severities across the landscape due to varying fuel load accumulations and other factors, particularly, in montane forests where pine-oak, mixed-conifer, and ponderosa pine (*Pinus ponderosa*) dominate the upper vegetative zones. Depending on the size of burn severity patches, these mosaics can fragment habitats, create edge effects, and change vegetative structure and composition. Therefore, understanding the impacts of these mosaic patterns of burn severities on wildlife species is ecologically important.

Wildlife

Common wildfire impacts on wildlife include direct mortality, injury, increased predation from lack of cover, or starvation from lack of food availability (fig. 2; DeBano and others 1998; Ream 1981). Generalist species, such as coyotes (*Canis latrans*) and great horned owls (*Bubo virginianus*), are typically not significantly impacted by wildfires since they may exhibit prey switching if other food resources are limited. Specialist species are more likely to be adversely impacted by wildfire than generalist species since specialists typically concentrate on a single resource. The ability for wildlife to survive wildfires depends on food availability, cover, mobility, behavior, and structural diversity (DeBano and others 1998; Lyon and others 1978; Patton 1992). Structural diversity is the uniformity, severity, size, intensity, season, and duration of the fire that creates edges between adjacent vegetative types (edge effect), creates snags that provide cover or cavities for use by wildlife, and creates environmental heterogeneity through the mosaic effect (DeBano and others 1998; Lyon and others 2000; Wright and Bailey 1982). Wildlife can be impacted by structural diversity if a wildfire burns uniformly at a moderate to high intensity rate across a large area due to lack of vegetation and cover throughout that landscape. Some highly mobile wildlife species will be able to travel long distances to emigrate from those areas; however, other wildlife species may try to emigrate but cannot get out of the

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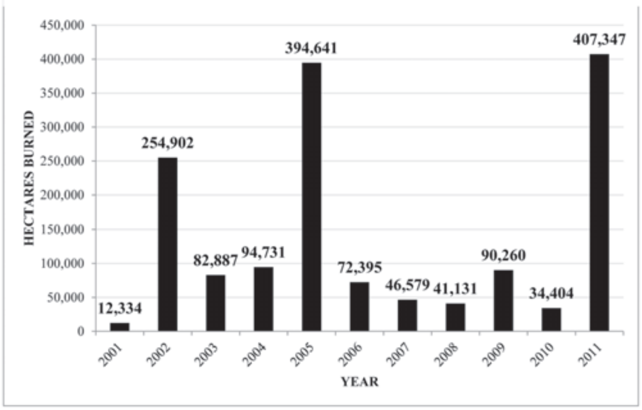

Figure 1—Hectares burned in Arizona 2001-2011.

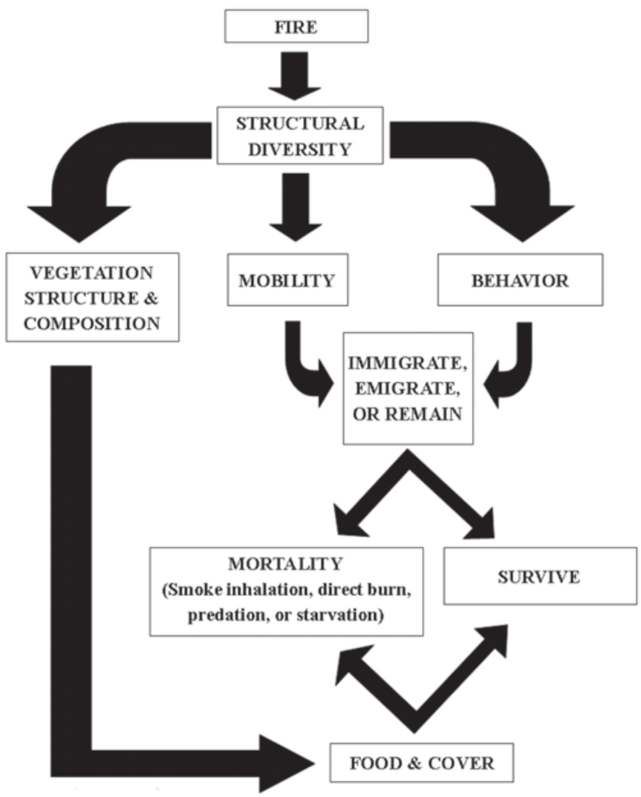

Figure 2—Impacts of fire on wildlife species. Arrows mean influences that can impact wildlife species.

moderate to high-severity patch. Ultimately, those species that cannot find their way out can potentially die of starvation or predation.

Most wildlife deaths during wildfires are due to smoke inhalation, direct burn, and behavior such as the inability or reluctance to evacuate (Bock and Lynch 1970; Buech and others 1977; Bulan and Barrett 1971; Chew and others 1959; Harrison and Murad 1972; Lyon and others 2000). Direct burns are a result of a wildfire that moves extremely fast and burns at an exceptionally high intensity, usually >63 °C, which is lethal to both small and large wildlife species (DeBano and others 1998; Howard and others 1959). Some wildlife species will not leave nests, burrows, cavities, or dens during fire, which subjects them to smoke inhalation and possibly death by suffocation. However, many fossorial mammals can survive wildfires since most burrow systems are extensive, subterranean tunnels that protect against heat intensity (Erwin and Stasiak 1979; Lyon and others 2000; Sutherland and Dickman 1999; Vernes 2000).

Wildfires that burn during the spring typically impact more wildlife species than wildfires that burn during any other season. Because spring is the time when breeding occurs for a majority of species, fires that erupt during this critical period can destroy nests, dens, burrows, or cavities and/or make them more open to predation by opening tree canopies or understory cover (Ward 1968). Adults are sometimes unable to emigrate from nests, dens, burrows, or cavities during fire due to the lack of mobility of offspring (Koprowski and others 2006; Lyon and others 2000). During fire, young animals are more prone to injury or mortality than adults; however, wildlife with high reproduction rates allow faster population recovery post-fire (Lyon and others 2000).

Granivores and Insectivores—Wildfire impacts granivore and insectivore species through loss of resources; however, some of these species respond positively to wildfires due to adaptation to open space or added food and cover over time (Lyon and others 2000). Birds in southeastern Arizona such as mourning doves (*Zenaida macroura*), vesper sparrows (*Pooecetes gramineus*), savannah sparrows (*Passerculus sandwichensis*), lark sparrows (*Chondestes grammacus*), horned larks (*Eremophila alpestris*; Bock and Bock 1992), and hairy woodpeckers (*Picoides villosus*) in northern Arizona forests (Covert-Bratland and others 2006) are typically found in burned areas due to an increase in seed production and insect infestations post-fire (Bock and Bock 1992, Covert-Bratland and others 2006). Woodpeckers emigrate into high-severity burns where most trees have been killed due to an abundance of insects and cavities (Lyon and others 2000), but home range sizes increase over time since the fire, which indicates that initially habitat quality increases but then is reduced over time (Covert-Bratland and others 2006). Other birds in southeastern Arizona such as Eastern meadowlarks (*Sturnella magna*), Cassin's sparrows (*Aimophila cassinii*), Botteri's sparrows (*A. botteri*), and grasshopper sparrows (*Ammodramus savannarum*), avoid burned areas for 2-3 years post-fire due to lack of grass and shrub cover (Bock and Bock 1992). Most birds will typically escape fire due to their extreme vagility (Erwin and Stasiak 1979; Gelluso and others 1986; Hakala and others 1971; Lyon and others 2000; Peres 1999); however, most ground-dwelling birds are likely to be adversely impacted by fire (Lyon and others 2000).

Small mammals also respond differentially to wildfire. Lack of food and/or predation are typical causes for small mammal decline within the first 2 months post-fire (McMurry and others 1996; Simons 1991). At Fort Huachuca Military Reservation, presence of species did not change post-fire for Merriam's kangaroo rat (*Dipodomys merriami*), silky pocket mice (*Perognathus flavus*), American deer mice (*Peromyscus maniculatus*), hispid pocket mice (*C. hispidus*), Northern grasshopper mice (*Onychomys leucogaster*), and Southern grasshopper mice (*O. torridus*), which indicates that these species did not emigrate from burned areas immediately post-fire (Litt and Steidl 2011). However, presence decreased on burned areas for Northern pygmy mice (*Baiomys taylori*), fulvous harvest mice (*Reithrodontomys fulvescens*), and Arizona cotton rat (*Sigmodon arizonae*), which may indicate direct mortality, predation from lack of cover, starvation from lack of food, or emigration to unburned areas immediately post-fire (Litt and Steidl 2011; Steidl and Litt 2009). Arizona cotton rat, fulvous harvest mice, and Merriam's kangaroo rat increased in abundance in burned areas while silky pocket mice, Northern grasshopper mice, and desert pocket mice (*Chaetodipus penicillatus*) decreased in abundance in burned areas (Litt and Steidl 2011; Steidl and Litt 2009). Abundances of yellow nosed cotton rats (*S. ochrognathus*), hispid pocket mice, and Northern pygmy mice did not change post-fire (Litt and Steidl 2011). In the Mazatzal Mountains, Ord's kangaroo rat (*D. ordii*), Merriam's kangaroo rat, cactus mice (*Peromyscus eremicus*), and pocket gophers (*Thomomys spp.*) use burned areas more than unburned areas, whereas Bailey's pocket mice (*C. baileyi*) use unburned areas more than burned areas (Monroe and others 2004). Merriam's kangaroo rats respond positively to burned areas due to being a generalist species and favoring open areas, which adversely impacts Bailey's pocket mice due to lack of cover (Price 1978; Rosenzweig and others 1975; Simons 1991).

Wildfire may adversely impact tree squirrels due to reduction of nests, cavities, and food resources (Kirkpatrick and Mosby 1981) and through creation of edge effects and fragmented habitat, but most squirrels temporarily emigrate during wildfire and are successful in avoiding wildfire (Bendell 1974). However, endangered Mt. Graham red squirrels (MGRS; *Tamiasciurus hudsonicus grahamensis*) in the Pinaleño Mountains are adversely impacted by large, intense stand-replacing wildfires since these types of catastrophic fires did not occur historically (Koprowski and others 2006). After the Nuttall fire in 2004, surveys were conducted to determine effects of wildfire on MGRS (Sanderson and Koprowski 2009). No MGRS carcasses were found but seven resident squirrels were not relocated post-fire (Koprowski and others 2006). However, a charred and dead Abert's squirrel (*Sciurus aberti*) was found (Greer, personal communication). Mt. Graham red squirrels require a midden, a long-term central cache site, for winter survival. These midden sites are typically located in dense, live portions of forest where greater amounts of seedfall occur, which may be severely impacted by catastrophic wildfires that opens forests and kills trees (Koprowski and others 2006; Wood and others 2007). The presence of small localized fire does not immediately trigger abandonment, as a MGRS was observed to continue to use a smoldering nest tree that had received a lightning strike (Merrick and others 2010). After surviving the direct effects of wildfire, many squirrel species respond positively to fire with equivalent or superior survival, decreased home range size in areas of reduced fire intensity and in areas where the fire did not reach the canopy, or use of burned areas more than unburned areas (Blount and Koprowski 2012; Doumas and Koprowski 2012; Gwinn 2011; Leonard and others 2010; Pasch and Koprowski 2011). Abert's squirrels introduced to Mt. Graham used areas within the perimeter of severe burns more than endangered MGRS (Gwinn 2011). Mexican fox squirrels (*S. nayaritensis*) used areas that experienced low-severity burn more than unburned areas and those that experienced higher burn severity, which indicates that this species is adapted to the low-severity fires that were historically experienced in the Chiricahua Mountains of southeastern Arizona (Doumas and Koprowski 2012).

Lizards are typically impacted by wildfire due to changes in vegetative structure and composition (Means and Campbell 1981; Russell and others 1999). In the southern Mazatzal Mountains near Four Peaks, lizard abundances in burned areas were greatest in chaparral and forest due to an increase in insect infestation post-fire (Cunningham and others 2002). In burned chaparral, Sonoran spotted whiptail (*Cnemidophorus sonorae*), Gila spotted whiptail (*C. flagellicaudus*), eastern fence lizard (*Sceloporus undulatus*), and ornate tree lizards (*Urosaurus ornatus*) were most abundant post-fire (Cunningham and others 2002). In unburned chaparral, collared lizards (*Crotaphytus collaris*) and short horned lizards (*Phrynosoma douglassi*) were most abundant (Cunningham and others 2002). Other lizards such as western whiptail (*C. tigris*), plateau striped whiptail (*C. velox*), and little striped whiptail (*C. inornatus*) use both unburned and burned chaparral (Cunningham and others 2002). However, western whiptail lizards decrease in abundance over time while other lizards increase in abundance in burned chaparral (Cunningham and others 2002). In burned forest, plateau striped whiptail, ornate tree lizard, Sonoran spotted whiptail, western whiptail, Gila spotted whiptail, collared lizards, western banded gecko (*Coleonyx variegatus*), and Great Plains skink (*Eumeces obsoletus*) were most abundant post-fire (Cunningham and others 2002). In unburned forest, short horned lizards and Madrean alligator lizards (*Elgaria kingi*) were most abundant (Cunningham and others 2002). Eastern fence lizards and little striped whiptail use both unburned and burned forest (Cunningham and others 2002).

Herbivores—Herbivores are primarily impacted by wildfire in the short-term due to loss of vegetation structure and composition. For this reason, most herbivores select unburned areas initially post-fire. However, once vegetative regrowth occurs, most herbivores will immigrate to burned areas. In the San Francisco Peaks, elk (*Cervus canadensis*) frequently use high-severity burn areas once aspen resprout occurred (Bailey and Whitham 2002). High-severity burn areas regenerate aspen ramets faster and with greater biomass than unburned, low-severity, and moderate-severity sites (Bailey and Whitham 2002). Elk continually graze high-severity burn areas for up to 3 years post-fire, which decreases aspen biomass, but aspen biomass increases by threefold in moderate-severity burn areas since elk herbivory was not prevalent (Bailey and Whitham 2002). Desert bighorn sheep (*Ovis canadensis mexicana*) in the Santa Catalina Mountains also use burned areas that open dense understory (Cain III and others 2005), since vegetative removal increases their visibility and ability to avoid predators (Etchberger and others 1989; Krausman and others 1996, 2001; Wakelyn 1987). Unburned areas with excessive, dense understory will be abandoned by sheep because these areas become unsuitable for sheep persistence (Krausman and others 1996). Burned areas had higher visibility measurements than unburned areas because unburned areas had an increase of vegetation over a 32-year period of fire suppression (Krausman and others 1996). Collared peccaries (*Pecari tajacu*) on the Three Bar Wildlife Area avoided burned desert scrub and chaparral areas for 1-2 years post-fire due to lack of cover and food resources such as cactus, acorns, and legumes (O'Brien and others 2005). Lower elevations in unburned chaparral and desert scrub were used more frequently by peccaries post-fire because these areas provided more thermal cover (O'Brien and others 2005). However, after 2 years, burned chaparral vegetation regenerates and provides as much cover as unburned chaparral (O'Brien and others 2005). Conversely, burned desert scrub vegetation did not completely recover, which indicates that these areas did not provide adequate cover for peccaries, even after 4 years post-fire (O'Brien and others 2005). White-throated woodrats (*Neotoma albigula*) in the Mazatzal Mountains were found to use unburned areas more than burned areas post-fire (Monroe and others 2004). Fire likely kills many woodrats since they usually do not emigrate from nests during fire (Quinn 1979; Simons 1991; Tevis 1956); however, woodrats that do emigrate during fire are found more frequently in unburned areas (Monroe and others 2004).

Carnivores and Omnivores—Wildfire impacts on carnivores and omnivores are rarely studied because most are generalists that are vagile and exhibit prey switching when main food resources are limited. Female black bears (*Ursus americanus*) in the Mazatzal Mountains used unburned patches 90% of the time (Cunningham and others 2003). Before the fire, female black bears with cubs used higher elevations to avoid males from predating their offspring;

however, females with cubs switched use from higher elevations to lower elevations post-fire likely due to lack of food resources and cover (Cunningham and Ballard 2004). Black bear survival post-fire is high; however, juvenile and female populations and cub recruitment declined (Cunningham and Ballard 2004). Male black bears primarily use burned areas and have larger home ranges post-fire (Cunningham and Ballard 2004), which indicate that resources were lacking in burned areas (Cunningham and others 2003). In the southern Mazatzal Mountains, gray foxes (*Urocyon cinereoargenteus*) use unburned areas more frequently than burned areas, while coyotes use both unburned and burned areas (Cunningham and others 2006). Gray foxes primarily use unburned areas because soft mast made up the majority of their diet (Cunningham and others 2006). Since over 90% of vegetation was lost post-fire, this influences gray foxes to decline in abundance likely due to starvation (Cunningham and others 2006). Coyote abundance did not seem to be impacted by wildfire, likely due to being a generalist species and an opportunistic predator (Cunningham and others 2006). In the Coconino National Forest and Coronado National Forest, Mexican spotted owls (*Strix occidentalis*) were not adversely impacted in the short term by presence or severity of wildfire, even though these forests have experienced catastrophic stand-replacing wildfires in the past (Jenness 2000). This outcome is likely due to owls being extremely vagile, generalist species.

Discussion

Wildfire can either positively or adversely impact wildlife species depending upon how intensely the fire burns, size of the burn severity patches, and the mosaic pattern left behind. Unfortunately, most studies do not incorporate these factors into their research design. Most forest dwelling wildlife species in the southwest are likely adapted to frequent, low-severity ground fires (Brown 1982; Humphrey 1974; Marshall 1963; Wright and Bailey 1982); however, increased fuel load accumulations from a century of fire suppression practices have created large, high-intensity crown fires and most wildlife species have not yet adapted to these conditions (Bendell 1974; DeBano and others 1998; Singer and Schullery 1989). Wildfire impacts wildlife species by reduction or loss of food and cover and overall changes in structural diversity (Lyon and others 1978; Lyon and others 2000; Patton 1992). Vagile, generalist species are probably only impacted by wildfire in the short term, since they will exhibit prey switching when resources are limited thus being able to find other food resources throughout a mosaic of burn severity types. Specialist and small, non-fossorial species are likely to be impacted the greatest by wildfire via direct mortality and loss of food resources and cover (DeBano and others 1998; Erwin and Stasiak 1979; Lyon and others 2000; Sutherland and Dickman 1999; Vernes 2000). Wildfires tend to create a more open forest understory and a mosaic of burn severities across the landscape that can fragment habitats, create edge effects, and change vegetative structure and composition. Some wildlife species tend to thrive in these areas, while others are hindered because they require cover to protect them from predation. Most mammal and avian predators increase their use of burned areas, which further exacerbates mortality of wildlife species post-fire (Lawrence 1966, Lyon and others 2000).

Management Implications

Fire is successful at reducing fuel loads, an important objective where fuel has accumulated to unprecedented levels, but may have adverse impacts on some wildlife species. Most studies do not distinguish use in burned areas. We suggest that research design must include use versus availability models to produce more significant results. We are also suggesting that burn severities must also be distinguished. This will allow managers to better understand how various burn severities can impact wildlife. Managers must understand life histories of individual wildlife species to understand how they may be impacted by wildfire and manage accordingly; however, effects of fire on many wildlife species are relatively unknown. Recent wildfires in Arizona emphasize our lack of knowledge about the short-term and long-term effects of wildfire on wildlife, while providing a unique opportunity to undertake such studies.

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