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**Effects of the Catastrophic Lone Fire on Low, Medium, and High Mobility Wildlife Species**

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**Federal Aid in Wildlife Restoration  
Project W-78-R**

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## INTRODUCTION

Frequent fire played a key role in the evolution of southwestern biota (Fulé et al. 1995) and maintained some of the most diverse vegetative communities found in North America. Flammability and the capability to recover from crown scorch are hypothesized to be adaptive characteristics in ponderosa pine (*Pinus ponderosa*). Frequent fires are essential in ponderosa pine forests for controlling pine tree population eruptions, forest litter accumulations, and recycling nutrients (Fulé et al. 1995). Further, some forb communities, which may contribute greatly to wildlife species diversity (Pase and Granfelt 1977), are seldom found on unburned ranges and require fire for growth to occur.

The ecological role of fire changed in the past century due to changes in land use, fire suppression, vegetative changes, and climate fluctuations (Kaib 1994). Before 1870, widespread fires occurred at least once per decade in southwestern ponderosa pine forests (Swetnam and Baisan 1996). This fire regime ensued from a cycle of wet winters (November - March), arid fore-summers (April - June), and dry lightning storms before summer monsoons (July - September). Average fire intervals in ponderosa pine sites on the Mogollon Rim (a steep escarpment from central Arizona to west-central New Mexico) ranged from 4-5 years, while fire intervals in mixed-conifer types to the north ranged from 6-10 years. Baisan and Swetnam (1990) found fire frequency (1697-1886) in the Rincon Mountain sky island, Arizona was dominated by large scale (>200 ha), early summer (May-July) fires every 6 years (range = 1-13 years). Large widespread fires were preceded by 2-3 years of greater than normal precipitation (El Niño) followed

by dry years (La Niña) (Swetnam and Betancourt 1990).

Fire frequency declines coincided with introduction of domestic sheep in the late 1870s and early 1880s. Severe overgrazing by sheep and cattle removed understory vegetation necessary to carry fires long distances (Bahre 1985, Savage and Swetnam 1990, Kaib 1994). Trails, fences, and roads also disrupted fuel continuity and reduced spread of fire (Swetnam and Baisan 1996). Active fire suppression maintained low fire numbers, particularly after World War II when surplus aircraft became available (Swetnam and Baisan 1996).

Current forest conditions are no longer like those before 1870. High tree density and large amounts of dead woody material are an artifact of fire exclusion (Fulé et al. 1995). These stands are likely unsustainable despite efforts of managers, because of their vulnerability to high-intensity fire or biological pathogens (Fulé et al. 1995). Catastrophic wildfires with high tree mortality (stand replacement), that are more numerous in modern periods, have been rare for many centuries. Yet, constantly accumulating fuels have no other means of elimination (Fulé and Covington 1994).

A catastrophic wildfire, the Lone Fire, burned 277 km<sup>2</sup> on the Four Peaks sky island area of the southern Mazatzal Mountains, Arizona from April 28 - May 14 1996. Severe drought conditions, record low fuel moistures, and strong winds resulted in the 2<sup>nd</sup> largest burn in Arizona history and burned >90% of the vegetation. Interior chaparral, Sonoran desert, and ponderosa pine/oak (*Quercus* spp.) Madrean evergreen forest were major vegetative types burned (USDA Forest Service 1996). Fire temperatures approximated 1,400 C, much higher than historical fire temperatures. In contrast to historical fire results, most ponderosa pines in the fire area were killed, and soils were left unprotected from erosion.

Effects of these larger, ecologically “unnatural” fires on many wildlife species are unknown.

Depending on a wildlife species mobility and habitat requirements, we suspect that fire affect species differently, especially on sky islands where whole habitats could be reduced in size or destroyed. We evaluated effects of fire and vegetation destruction on low, moderate, and high mobility wildlife species. Specifically, we focused on the following species or groups: lizards; small mammals, primarily rodents; mid-sized carnivores, specifically gray fox (*Urocyon cinereoargenteus*), bobcats (*Lynx rufus*), and coyotes (*Canis latrans*); and black bears (*Ursus americanus*).

## STUDY AREA

The 245-km<sup>2</sup> study area was approximately 80 km northeast of Phoenix, Arizona in the southern portion of the Mazatzal Mountains, and included the Four Peaks and Mt. Ord sky islands (Fig. 1). Elevations ranged from 700-2,300 m, with steep, rocky topography and many >45% slopes.

Annual precipitation averaged 63 cm at the nearest weather station in Roosevelt, Arizona (720 m). However, there is a relatively constant precipitation gradient of 1 cm per 300 m elevation. Temperatures range from – 5 C in winter to >39 C in summer (Western Regional Climate Center 1999), with an altitudinal temperature gradient of 1 C per 100 m elevation.

Four Peaks and Mt. Ord are representative southwestern desert sky islands, with mixed conifer and ponderosa pine stands at higher elevations, surrounded by interior chaparral and Sonoran desert scrub at lowest elevations. The primary vegetation type was interior chaparral (Brown and Lowe 1974), a complex association of shrubs and short (<2 m) trees.

Shrub live oak (*Q. turbinella*) and manzanita (*Arctostaphylos pungens*) often dominated locally, but >50 chaparral species were identified during this study. Major drainages consisted of riparian communities including both deciduous and evergreen forest species. After the Lone Fire, 2.2 km<sup>2</sup> of ponderosa pine forest were left from the original stand of 10.3 km<sup>2</sup>, and 28.8 km<sup>2</sup> of Madrean evergreen woodland burned, leaving 11.9 km<sup>2</sup> unburned. Mt. Ord, a smaller sky island, had a mix of ponderosa pine and Madrean evergreen forest covering approximately 17.7 km<sup>2</sup> at higher elevations.

## LIZARD COMMUNITIES

The effects of fire on low mobility animals like lizards are ambiguous. Lillywhite (1977) and Kahn (1960) found lizard numbers and diversity increased in southern California chaparral after a fire. In Florida sandhill communities, Mushinsky (1985, 1992) found a whiptail (*Cnemidophorus sexlineatus*) benefited from high fire frequency, whereas a skink (*Eumeces inexpectatus*) was negatively impacted. Many lizards depend on the horizontal and vertical structure of live vegetation (Pianka 1966, 1973). Due to the extreme temperatures and extensive amount of vegetation burned, we expected direct mortality and reduced lizard populations. To evaluate this, we measured lizard abundance (numbers), species richness (number of different species), diversity and evenness (proportion of different species) between burned and unburned vegetation types post-fire. We correlated overall lizard abundance and richness with specific habitat variables such as distance to the edge of the burn, vegetation structure at different height intervals, elevation, and the forest island size of Four Peaks and Mt. Ord.

We were surprised to find that lizard community abundance and diversity

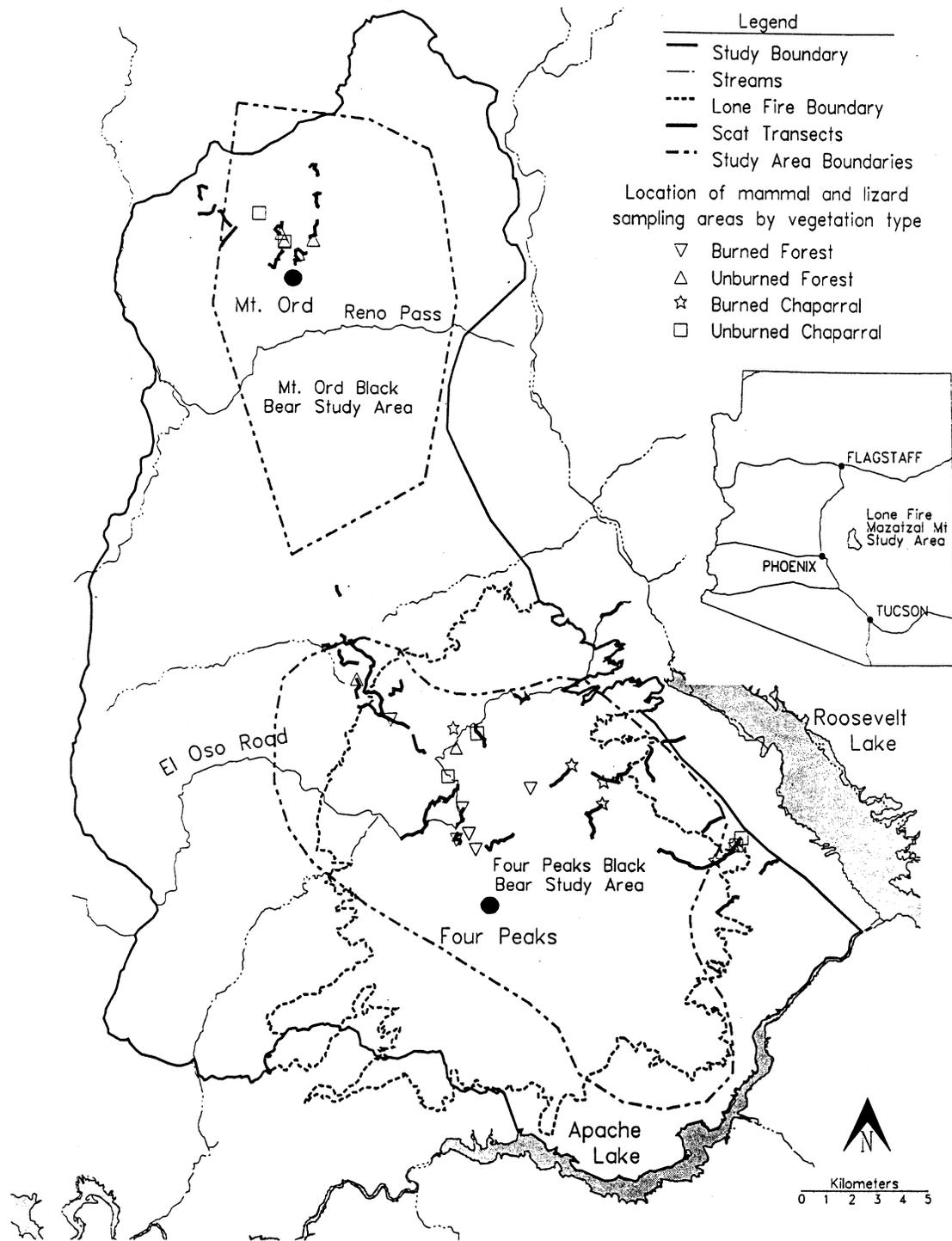


Figure 1. Map of the study area in the Mazatzal Mountains, Arizona, 1996-2000, including the Lone Fire boundary, Four Peaks and Mt. Ord sky islands, and the locations of each pitfall trap array, small mammal sampling grids, predator scat transects, and both black bear study areas.

increased in both burned chaparral and forest, with the increase in burned forest the greatest. Species with less specific habitat requirements (generalists) and larger home ranges such as whiptails and eastern fence lizards (*Sceloporus undulatus*) seemed to benefit most from the burn. The high presence of juveniles and adults so far from the edge of the burn, and the mating success of bisexual whiptails over unisexual species led us to believe there was high fire survivorship. We hypothesized the increased food resources in burned areas allowed for increases in numbers, and vegetation structure was not as important. All lizard community values were higher on Four Peaks (burned or unburned), than the smaller Mt. Ord.

### Field Efforts and Analyses

1. Lizard sampling array transects were established in 4 vegetation types; burned and unburned chaparral and burned and unburned forest. We sampled all 4 types on Four Peaks, and unburned chaparral and forest on Mt. Ord for comparison.
2. Each array consisted of 4 13.3 L pitfall buckets, dug into the ground in a “Y” configuration, with a 20-cm fence between each bucket to direct animals into buckets. Traps were checked at 3-day intervals during September 3 - October 1 1996, June 23 - September 28 1997, July 7 - October 6 1998, and July 20 - October 29 1999. Captured lizards were identified, aged to juvenile or adult, and released in nearby cover. We sampled >8,000 bucket days (~ 2,000/treatment) per year in 1997-1999, and with limited sampling in 1996, total effort was 26,214 trap days.
3. Lizard abundance (% of traps capturing lizards/number of days) and species richness were computed each year and at the end of each 8-day trapping period. We used Shannon’s  $H'$  as a diversity index to characterize each species in the community. Hill’s  $N_2$  (Ludwig and Reynolds 1988) determined the number and which species in each community were considered abundant. Hill’s  $E_5$  compared proportions of species within a community (evenness).
4. A Kruskal-Wallis test was used to test for differences in abundance, richness, diversity, and evenness among vegetation types and years. To compare abundance and richness on Four Peaks versus Mt. Ord, we used a Mann-Whitney  $U$  test. We used linear regression models to determine if lizard species abundance or richness correlated with distance from the edge of the burn or elevation. Differences were considered significant when  $P < 0.05$ ; exact  $P$  values are not given.
5. We measured live vegetation cover using 25-m line intercepts in the first week of September each year. Ground cover by vegetation was measured at the following height intervals: 0.0 - 0.15 m, 0.16 - 0.3 m, 0.31 - 0.9 m, 0.91 - 1.8 m, 1.9 - 4.6 m, and >4.6 m along each transect. Stepwise multiple linear regression models were used to compare all species abundance, individual species abundance, and richness with vegetation cover at different heights.

### Effects on lizard abundance, richness, diversity, and species composition

*Among Vegetation Types* - Lizard abundance in burned chaparral ( $\bar{x} = 14.4\%$ ) and burned forest (11.7%) was significantly greater than unburned chaparral (6.1%) and unburned forest (2.8%). Lizard abundance differed among years in all vegetation types and was greatest in 1998 (Table 1). Mean

Table 1. Lizard community values as determined from pitfall captures in burned and unburned chaparral, and burned and unburned forest on Four Peaks and Mt. Ord in the Mazatzal Mountains, Arizona, 1997-99.

Vegetation Type		1997	1998	1999
Burned Chaparral	N=	2,120	2,220	2,100
	# lizards/trap day	0.12	0.18	0.05
	Species richness	15	14	15
	Species evenness E5	0.47	0.47	0.71
	Shannon's H'	1.5	1.4	2.1
	Hill's N2	2.6	2.5	6.1
Unburned Chaparral	N=	1,570	1,640	2,100
	# lizards/trap day	0.03	0.09	0.04
	Species richness	13	12	12
	Species evenness E5	0.79	0.53	0.45
	Shannon's H'	2.0	1.4	1.9
	Hill's N2	6.6	6.6	4.5
Burned Forest	N=	1,900	2,160	3,064
	# lizards/trap day	0.09	0.14	0.09
	Species richness	13	12	10
	Species evenness E5	0.4	0.5	0.48
	Shannon's H'	1.2	1.4	1.4
	Hill's N2	1.9	2.5	2.4
Unburned Forest	N=	2,220	2,140	2,980
	# lizards/trap day	0.02	0.03	0.01
	Species richness	4	4	7
	Species evenness E5	0.52	0.6	0.52
	Shannon's H'	0.7	0.7	1.1
	Hill's N2	1.5	1.5	2.1

species richness in unburned forest ( $\bar{x} = 5.0$ ) was significantly less than in burned chaparral (14.7), burned forest (11.7), or unburned chaparral (12.3). Diversity was greatest in chaparral (burned and unburned), and least in unburned forest. The number of abundant species (N2) was greatest in unburned chaparral ( $\bar{x} = 5.9$ ) and least in unburned forest ( $\bar{x} = 1.7$ ). Evenness was similar in all vegetation types. The ratio of juveniles:adults captured increased through

September each year, but the change was never significant. Limited 1996 data, collected only in September, were similar to 1997-1999 data with lizard abundance greatest in burned chaparral. The proportion of juveniles was also greater in burned sites.

*Chaparral* - Almost all measures of lizard communities were greater in burned chaparral than unburned. Burned chaparral abundance was 75 to 50% higher than unburned chaparral in 1997 and 1998,

respectively. In 1999, abundance was similar. More species were captured each year in burned chaparral than any other vegetation type, but the 3-year overall total (16) was greatest in unburned chaparral. The proportion of juveniles captured decreased in 1999 (30.5%) from previous years (59%).

Western whiptails (*Cnemidophorus tigris*) seemed to benefit most from the burn in chaparral, as they were the most frequently captured species in burned chaparral (52%, Appendix 1), and were 8 times more numerous than in unburned chaparral. The western whiptail was also 10 times more abundant than any other Teiidae (whiptails and their allies) species captured in burned chaparral. However, the proportion of this species captured declined from 1997-1999 (65-32%).

Evenness and diversity increased in burned chaparral in 1999 as the proportion of western whiptails decreased. Eastern fence lizards were the next most common species and the only member of the Phrynosomatidae family considered abundant (N2) in burned chaparral. Conversely in unburned chaparral, eastern fence lizards were captured most (48%), followed by western whiptails (19%). In burned chaparral, 5 Teiidae family species including western whiptail, Sonoran whiptail (*C. sonorae*), Gila spotted whiptail (*C. flagellicaudus*), plateau whiptail (*C. velox*), and little striped whiptail (*C. inornatus*) were considered abundant (N2). The desert grassland whiptail (*C. uniparens*) was also caught, but was not considered abundant. In unburned chaparral, only 3 whiptail species, western, little striped, and plateau striped were considered abundant (N2). Phrynosomatidae such as tree lizards (*Urosaurus ornatus*) were much more common in burned than unburned chaparral.

*Forest* - The greatest difference in lizard communities between burned and unburned vegetation was seen in forest habitats. Lizard abundance was 2<sup>nd</sup> greatest in burned forest each year, and was 4 to 9

times greater than in unburned forest (depending on the year). Burned forest abundance values differed significantly between years, but richness did not. Unburned forest had the lowest lizard abundance, richness, and diversity each year and overall.

Fourteen species were captured in burned forest versus 9 in unburned forest. The most common in both sites were the eastern fence and little striped whiptail lizards, but numbers were 3 to 9 times greater in burned forest. Lizard species and number captured in burned forest, but not unburned, included the Sonoran whiptail (16), collared lizard (*Crotophytus collaris*) (11), banded gecko (*Coleonyx variegatus*) (7), Gila spotted whiptail (7), western whiptail (7), and the great plains skink (*E. obsoletus*) (4).

*Explanations of changes* - The Lone Fire increased lizard community abundance, richness, and diversity in both chaparral and forest. The proportional increase in abundance and richness was greater in burned forest than burned chaparral. Natural history characteristics of each lizard species including foraging strategy, home range size, reproductive strategy (number of eggs and clutches, unisexual versus bisexual), and habitat requirements could all affect colonization rates into a fire-disturbed site.

We believe fire survivors made up the majority of residents in post-fire lizard communities. The Lone Fire occurred prior to lizard species laying eggs, so presence of juveniles in 1996 indicates survivorship of adults and the proportion of juveniles to adults was similar in burned and unburned sites that year. We captured more lizards in burned sites than adjacent unburned 3 months after the fire, and many juveniles were captured >4 km from the edge of the burn.

The 2 most common whiptails were bisexual species, and the 4 less common were unisexual. If mortality during the fire was substantial, we would have expected

unisexual species to have an advantage because they would not have to find a mate to reproduce. The greater abundance of bisexual western and little striped whiptails in burned sites over unburned indicates little fire mortality, as there could not have been a problem finding mates for these species. In experimental studies, Massot et al. (1992, 1994) found a prior-residence advantage in ability of individuals to face a new environment.

Although not measured, we observed an increase in food in burned vegetation due to insects infesting dead wood and an increase in grass and forb species. Lizards in southern California increased and shifted home ranges to take advantage of food resources post-fire (Kahn 1960, Lillywhite and North 1974, Lillywhite 1977) and food increases can directly influence lizard density and species diversity (Pianka 1973, Vitt et al. 1981). Increase in food resources has been linked to increases in body size, clutch size, diet, and home range size within species of whiptails (Pianka 1970, Vitt et al. 1997, Eifler and Eifler 1998).

The large home range of the eastern fence lizard may enable individuals to find open areas (density sinks) more frequently than other Phrynosomatidae (M'Closkey and Hecnar 1994). Conversely, the small territory size and arboreal nature of the tree lizard could limit them from finding these sites and may explain abundance differences between the 2 species.

### **Relationships with Habitat**

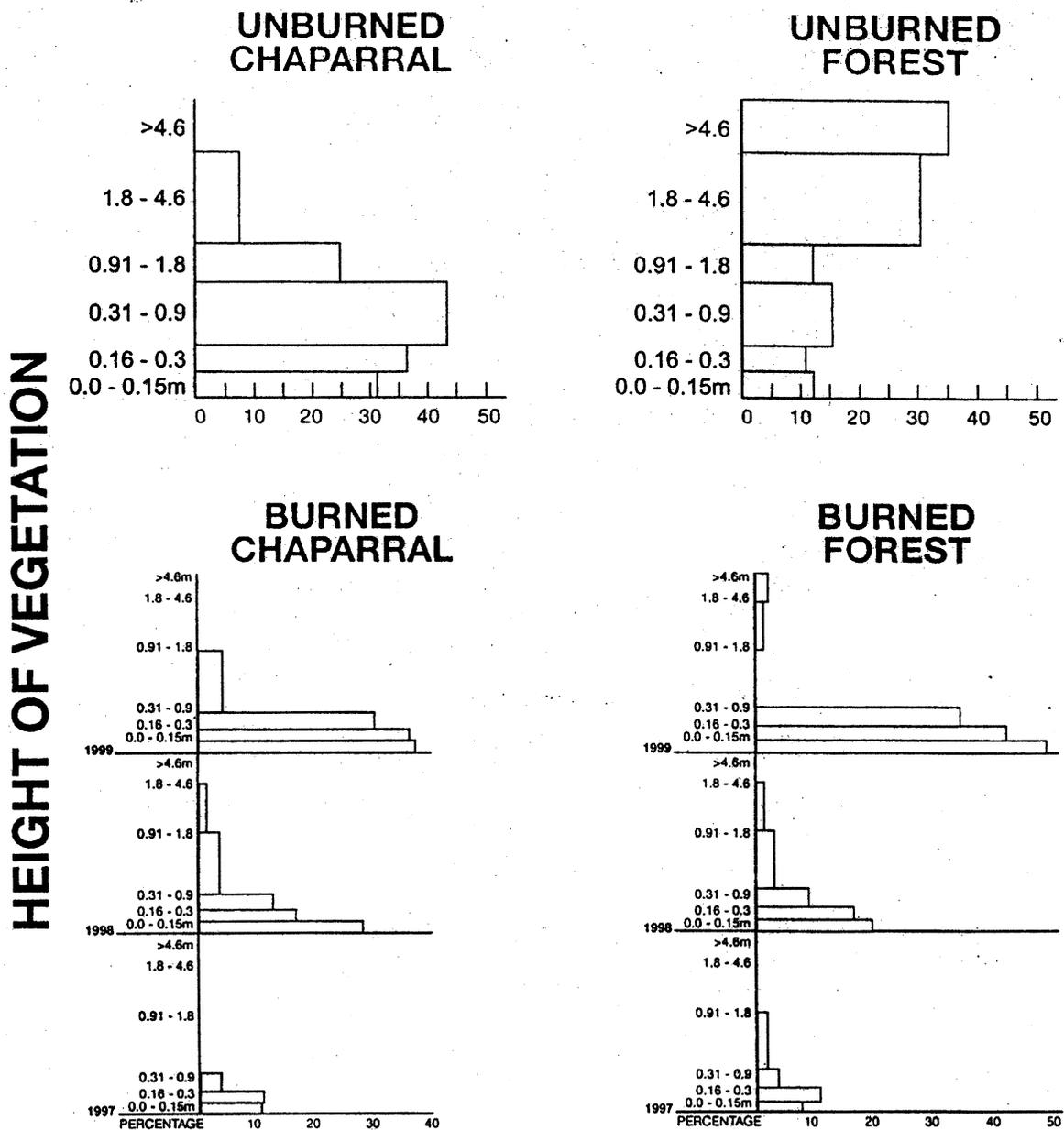
Regressions between distance to the fire edge and lizard abundance were significant, but weak in both burned chaparral ( $r^2 = 0.08$ ) and forest ( $r^2 = 0.18$ ), so we did not find the correlation helpful. The same was true with the regression of species richness in burned chaparral ( $r^2 = 0.16$ ). The regression between richness and distance to

the fire boundary was not significant in burned forest.

*Vegetation Structure* - The lack of a strong relationship between distance to fire edge and lizard abundance and richness further indicates high fire survival. Both Chew et al. (1959) and Simons (1989) found that small vertebrates were more likely to be killed directly by fire than larger vertebrates, but others have documented lizard survival (Kahn 1960, Lillywhite 1977).

Vegetation cover was similar each year in both unburned sites, but increased each year within burned areas (Fig. 2). In a series of stepwise regression models, surprisingly, we did not find a relationship between overall lizard abundance and vegetation cover. We did find a significant relationship with elevation ( $r^2 = 0.92$ ) and western whiptail abundance. We found western whiptail lizard abundance greatly increased as elevation decreased. We also found a relationship between eastern fence lizard abundance and burned forest. A Kruskal-Wallis test determined that eastern fence lizard abundance differed between vegetation types and burned forest had the highest ranking.

*Four Peaks vs. Mt. Ord* - Lizard abundance, species richness, and diversity have been correlated with vertical and horizontal vegetation diversity (Pianka 1966, 1973), amount of thermal cover (Adolph 1990), and presence or absence of certain plant species (Szaro and Belfit 1986). Hence, we expected catastrophic fire to reduce rather than increase lizard abundance. However, abundance and diversity were greatest in burned vegetation from 3 months post-fire to >3 years later, indicating suitable habitat for many species. Burned vegetation types appear to have enough microsites, food resources, and cover for more species, both sexes and age classes to coexist and increase.



## PERCENT OF CANOPY COVER

Figure 2. Mean vegetation cover by height interval and vegetation type measured at each pitfall transect from 1997-1999 in the Mazatzal Mountains, Arizona.

Lack of relationship between lizard abundance and vegetation may indicate greater microhabitat selection than expected, insufficient vegetation sampling, or both. We did not sample dead material, therefore, some vegetative structures (charred stumps, downed trees, and branches) were not measured. Arboreal species (*Sceloporus* spp.) that use tree trunks or shrub bases (e.g., *Urosaurus* spp.) still present as charred stumps, were more numerous than those that use outer branches.

Our initial design assumed lizard community characteristics in unburned vegetation types on Mt. Ord and Four Peaks would be similar. However, Mt. Ord had significantly less abundance and richness in both unburned chaparral and forest during all years. Abundance on Mt. Ord was less than half that on Four Peaks each year, and total Mt. Ord richness was 7 as compared to 17 on Four Peaks. We found no vegetation cover differences between the 2 peaks.

The lower numbers of lizards on Mt. Ord, when compared to Four Peaks, was an unexpected, but important finding. Pre-Lone Fire, Four Peaks was a larger forested island (51 km<sup>2</sup>) than Mt. Ord (17.7 km<sup>2</sup>). Jones et al. (1985) found mountain island size affected lizard species richness, and species on smaller islands were subsets of species from similar larger islands, which we noted. However, since chaparral is contiguous from Four Peaks to Mt. Ord, this would not explain the difference in richness and abundance in chaparral vegetation.

We stress a careful interpretation of these results since they are short-term effects. We predict different long-term results for species more common in forests than chaparral. In 4 years since the fire, we have not noted any ponderosa pine reproduction, and the pine forest may not return (Swetnam et al. 1999). The long-term effect of losing the ponderosa pine component will not be determined for many

years. Decreased lizard diversity and abundance is likely for pine forest adapted lizard species. Germano and Hungerford (1981) found a significant reduction in lizard species in an area where mesquite trees (*Prosopis* sp.) had been cleared 22 years prior to surveys.

We expect continued growth in chaparral communities to reduce lizard abundance, but not species richness. We believe chaparral and the associated lizard community are fire dependent, based on our observations.

## SMALL MAMMALS

Although Chew et al. (1959) and Simons (1989) found smaller vertebrates (i.e., rodents, other small mammals, reptiles) were more likely to be killed by fire than larger animals, large numbers of small mammals have survived after burns either by burrowing or emigration (Lyons 1978, Clements and Young 1996, McMurry et al. 1996). However, studies that documented high immediate survival, found that small mammal populations declined 2 weeks to 2 months after fire due to increased predation or lack of food (Simons 1991, McMurry et al. 1996). Food availability and cover can influence small mammal abundance and may affect species differently (Krefting and Ahlgren 1974, Fa and Sanchez-Cordero 1993).

We started sampling small mammals in 1997 to determine if differences in small mammal abundance, species richness, and species composition occurred from 1 until 3½ years post-fire. We did not see the difference in overall small mammal abundance we expected, given results from previous studies. Overall small mammal abundance was not different between burned and unburned sites, but some Heteromyidae (kangaroo rats, pocket mice, and allies) species increased in burned chaparral.

White-throated woodrats (*Neotoma albigula*) were negatively affected by the burn. Seasonal small mammal differences were probably due to species having their young during different months (Hoffmeister 1986). Similar to lizards, there were more species present in higher numbers on Four Peaks than Mt. Ord.

### Field Efforts and Analyses

1. We sampled small mammals in burned and unburned chaparral and forest on Four Peaks, and unburned chaparral and forest on Mt. Ord. Sherman and wire live traps, and pitfall traps (see lizard field efforts) were used to capture small mammals. We used 3 trap types to reduce bias because species show differential trapability for each trap type (Williams and Braun 1983, Maddock 1992). We checked traps each morning of a 4-night trapping session, and each animal captured was identified to species (Burt and Grossenheider 1980).
2. For each vegetation type we sampled small mammals a minimum of 240 trap nights in summer 1997 (July 9 – September 28), fall 1997 (September 30 – November 21), spring 1998 (March 9 – April 10), summer 1998 (May 29 – October 6), fall 1998 (October 15 – November 17), and pitfalls were run each summer (July – September).
3. Abundance and species richness were determined for each vegetation type each trapping season. We used Shannon's H', Hill's N2, and Hill's E5 indices to characterize small mammal community relationships in burned and unburned vegetation types. We used a Kruskal-Wallis test

to test for differences between burned and unburned communities.

### Effects on small mammal abundance, richness, and species composition

*Among vegetation types* - We had considerable variability and minimal small mammal capture rates in each sample. Abundance and species richness were not significantly different between burned and unburned vegetation (Table 2). Species richness, however, increased significantly in burned vegetation as vegetation succession proceeded. Overall, small mammal diversity and evenness values were greatest in burned chaparral and were greater in burned than unburned forest. Seasonally, summer 1998 had the greatest overall small mammal diversity. But, due to minimal capture numbers, we did not compute diversity or evenness values for all seasons. We only captured 27 small mammals in 26,214 pitfall trap nights (in 4 years) in all vegetation types.

*Chaparral* - Heteromyidae species seemed to benefit from the burn. We captured 6 Heteromyidae species in burned chaparral, most with greater abundance than in unburned chaparral. Only 4 heteromyids were captured in unburned chaparral. In our last live trapping session, 30 months post-fire, species composition was still different between burned and unburned sites as abundance of Ord's kangaroo rat (*Dipodomys ordii*) and brush mouse (*Peromyscus boylii*) were greater in burned sites.

Small mammal abundance of 6 species in chaparral differed significantly either between burned and unburned sites or seasonally. Ord's and Merriam's (*D. merriami*) kangaroo rats were captured more in burned chaparral. Bailey's pocket mouse (*Perognathus baileyi*) was captured more in unburned chaparral. Only 1 white-throated woodrat was captured in burned chaparral,

Table 2. Small mammal community values as determined from live trapping in burned and unburned chaparral, and burned and unburned forest on Four Peaks and Mt. Ord in the Mazatzal Mountains, Arizona, 1997-98.

Trapping session Vegetation type	Abundance (CPU)	Richness (# of species)	Diversity (Shannon's H')
Summer 1997			
Burned Chaparral	4.2	4	1.12
Unburned Chaparral	1.0	1	1
Burned Forest	0	0	0
Unburned Forest	1.1	2	0.68
Fall 1997			
Burned Chaparral	5.0	6	1.36
Unburned Chaparral	0	0	0
Burned Forest	1.3	1	0.56
Unburned Forest	2.5	2	0.8
Spring 1998			
Burned Chaparral	4.7	1	0
Unburned Chaparral	1.1	6	1.47
Burned Forest	1.0	1	0
Unburned Forest	2.6	3	0.36
Summer 1998			
Burned Chaparral	3.8	7	1.60
Unburned Chaparral	5.8	5	0.93
Burned Forest	0.9	3	0.85
Unburned Forest	5.2	4	0.73
Fall 1998			
Burned Chaparral	5.4	5	1.42
Unburned Chaparral	4.6	6	1.32
Burned Forest	4.3	5	1.10
Unburned Forest	0.6	3	1.04

whereas 10 were captured in unburned chaparral. Cactus mouse (*Peromyscus eremicus*) abundance increased more in burned sites as post-fire time increased (Appendix 2).

Pitfall trap success was poor compared to live traps. In burned chaparral we captured only 2 pocket gophers (*Thomomys* sp.) and 2 cactus mice in 4,440 trap nights. In unburned chaparral we captured 1 long-tailed pocket mouse (*Perognathus formosus*) and 1 desert shrew (*Notiosorex crawfordi*) in 5,310 trap nights.

The first year after a fire, both insects and annual grasses and forbs increase and can be an important food source for small mammals. The Lone Fire also increased stumps and fallen logs, which small mammals use for hiding and living space (Lowe et al. 1978). We found heteromyids responded positively to early successional growth in chaparral, which provided an additional seed source following fire.

Species whose primary microhabitat is augmented by fire and early succession are likely to show rapid increases after fire (Fox

1990), and small mammal species may exhibit a mammalian succession similar to vegetation.

Simons (1991) also observed a greater capture rate of white-throated woodrats in unburned chaparral versus burned vegetation. He speculated that fire negatively affected woodrats by destroying nests or middens, structures that take years to build.

*Forest* - Although no differences were statistically significant, we found some differences in small mammals between burned and unburned forest. We captured more species in burned ( $n = 8$ ) than unburned ( $n = 5$ ) forest. Brush mice and cactus mice were the most abundant species in burned forest. Brush mice were the most common species captured in unburned forest (but cactus mice were never captured in unburned forest). The white-throated woodrat was the only species captured in unburned forest that was not captured in burned forest.

Although success was very low, we caught more animals in pitfall traps in burned forest. We captured 17 small mammals in 7,124 trap nights, including 6 deer mice (*Peromyscus maniculatus*), 4 brush mice, 5 desert shrews, and 2 pocket gophers. In unburned forest, we captured 4 deer mice and 1 desert shrew in 7,340 trap nights.

Apparently, reduction of underbrush and canopy cover at forest sites allowed some species to increase that we did not expect. Contrary to their natural history, cactus mice, usually a Sonoran desert species (Hoffmeister 1986), may have preferred burned forest because of open understory canopy, increased insect abundance, fresh green vegetation, and burrow availability. Seventy-one percent of desert shrews were captured in burned vegetation, which differs from Gashwiler's (1970) findings that shrews were more

common in unburned forests. Perhaps the increase in insects that occurred allowed desert shrews to survive within the burn.

### **Differences Between Sky Islands**

Similar to our lizard results, we detected species composition differences between the 2 sky islands. Bailey's pocket mouse was captured 68 times in unburned chaparral on Four Peaks, but never on Mt. Ord. Deer mice were captured in both unburned vegetation types on Mt. Ord, but only unburned forest on Four Peaks. Four Peaks had greater species richness than did Mt. Ord.

We don't understand why Bailey's pocket mouse, the most common heteromyid in Four Peaks unburned chaparral, was not captured on nearby Mt. Ord, since chaparral is contiguous from Four Peaks to Mt. Ord. This may be due to large blocks of upper Sonoran desert scrub adjacent to interior chaparral on Four Peaks, and not Mt. Ord.

### **MID-SIZED CARNIVORES**

Previous research documented varied response to fires by mid-sized carnivores. Badger (*Taxidea taxus*), bobcat, and coyote densities increased following fire (Lawrence 1966, Gruell 1980, Patton and Gordon 1995), and increases were attributed to greater prey vulnerability due to loss of hiding cover. However, fires can reduce prey populations, which may decrease predator numbers (Rabinowitz 1990, Poole et al. 1996). Ogen-Odoi and Dilworth (1984) determined that hare (Leporidae) populations increased 3 months after a prescribed burn in savanna grassland, but predator numbers were not affected.

Based on these studies, we wanted to determine if changes in population density of gray fox, coyote, and bobcat occurred, and if there were changes in the ratio of gray fox:coyotes:bobcats in burned vegetation.

Therefore we investigated the effects of the Lone Fire on the density of these 3 species. Since predator density changes were linked to food supply, we examined diet of the 3 carnivores in burned and unburned vegetation and determined if each species density was independent of small mammal availability. Mid-sized carnivore group size, density, and home range size has been linked to food availability (Beasom and Moore 1977, Gese et al. 1988, Mills and Knowlton 1991).

We found a reduction and return to pre-fire density of all 3 carnivore populations, and believe this was primarily due to changes in food and cover. Gray fox primarily depended on mast crops, and this food source was destroyed except in green islands missed by the burn. Coyotes utilized small mammals more often, which may have been more vulnerable post-fire. Coyotes increased immediately after the burn, and then decreased, possibly following small mammal availability.

#### Field Efforts and Analyses

1. We collected gray fox, coyote, and bobcat scats on transects in burned and unburned vegetation (Fig. 1). Permanent transects were  $\geq 1$  km in length on unmaintained roads or hiking trails. We cleared all predator scats, then we surveyed the same transects 10-15 days later and collected all carnivore scats. To identify scats, we used descriptions by Murie (1954) and Danner and Dodd (1982). Indices were calculated by: (# of scats from species x) / (# of nights between when scats were cleared and collected) X 100.
2. We collected pre-fire data in March 1996 and determined the statistical minimum estimateable difference (how great of a difference there needed to be to detect a significant difference) for each species ( $\beta = 0.9$ ,  $\alpha = 0.05$ , Zar 1984) for scat survey indices.
3. We collected scats on 19.5 km of transects in burned vegetation and 27.2 km in unburned during the breeding season (February - April), whelping and weaning period (May - July), and juvenile dispersal (September - November). We did not separate transects by chaparral or forest vegetation. Sampling began in March 1996 (pre-burn) and ended in fall 1998. We used a Kruskal-Wallis test to compare scat indices within the same species over time. A *t*-test was used to test mean differences in ratios between coyote and gray fox.
4. All gray fox ( $n = 690$ ), coyote ( $n = 165$ ), and bobcat ( $n = 30$ ) scats collected were labeled within the 10-15 day interval they were collected. Scats were dried, washed through a series of sieves, examined against a white background through a stereoscope, and separated by food type. We used reference seed and mammal hair collections and hair descriptions from Moore et al. (1974) to identify scat contents. Food items were reported as frequency of occurrence (the percent of time they occurred in scats) by year, season, and burned and unburned sites. Horn's (1966) overlap index was used to measure diet overlap within species and between coyotes and gray fox.
5. We used linear regression to examine the relationship between small mammal abundance and predator scat indices.

### Effects on Carnivore Density

The Lone Fire had a negative effect on gray fox for almost 2 years. Gray fox density declined rapidly after the fire (Fig. 3) and was significantly (>69% difference) less than pre-burn or unburned areas in fall of 1996 and spring of 1997. Gray fox scat density also declined in unburned vegetation during the same period, but the difference may have been due to sampling (not statistically different). Gray fox density in burned sites was greatest and similar to unburned areas in 1998.

Coyote density was statistically similar among years and between burned and unburned sites. In burned vegetation, density was lowest in 1997 and greatest in the summer of 1998 (Fig. 4). Although not statistically different, coyote scat density in burned sites immediately following the fire was 25% greater than pre-burn, then rapidly declined.

Bobcat scat density in burned and unburned sites had the greatest variability among samples. Bobcat density in burned sites declined to 0 in 3 out of the next 4 seasons, but density in the unburned vegetation declined as well. It appears bobcats left the burn perimeter but returned to pre-fire levels by 1998. Variability made it difficult to detect a trend.

Although the mean coyote:gray fox ratio in burned versus unburned sites was not statistically different, the ratios were higher in burned areas the first year post-fire. Because of the high variability in bobcat density we could not detect any trend in bobcat:coyote or bobcat:gray fox ratios. There was no linear relationship detected among the 3 carnivore densities and small mammal abundance in burned or unburned sites.

Post-fire mortality and movements of transmittered foxes, bobcats, and coyotes support initial density declines. Four

transmittered gray fox within the burn survived the fire, but within 2 weeks made longer movements along unburned riparian corridors than did fox in unburned areas. All 4 gray fox stayed within the burn perimeter, but died within 2 months. One coyote captured within the burn perimeter moved out of burned vegetation and only returned sporadically as vegetation resprouted. Both transmittered bobcats moved out of the burn after 3 weeks.

Post-fire carnivore decline contrasts results by Patton and Gordon (1995), Gruell (1980), and Lawrence (1966) that mid-sized carnivores initially increased after a fire. Coyotes increased initially, but none of the above studies attempted to monitor carnivore numbers >6 months. It is possible that this discrepancy occurred because the Lone Fire killed so much vegetation (>90%).

Major and Sherburne (1988) and Theberge and Wedeles (1989) found that fox spatially avoided coyotes and coyotes consumed fox in western Maine. Gray fox density increased in 1998, when coyote density was greatest, so spatial avoidance was not indicated. Coyote predation on gray fox was minimal as no gray fox remains were found in coyote scats.

### Effects on Carnivore Diet

The primary gray fox food type was soft mast (berries), and other common foods included rodents, insects, and rabbits (Appendix 3). The most common soft mast eaten was manzanita, one-seeded juniper (*Juniperus monosperma*), serviceberry (*Amelanchier bakerii*), and prickly pear (*Opuntia engelmannii*). The lowest similarity values were between diets in burned and unburned areas was in 1996 and 1997, 1998 diets were similar. Seven food items were recorded in scats within

## Gray Fox

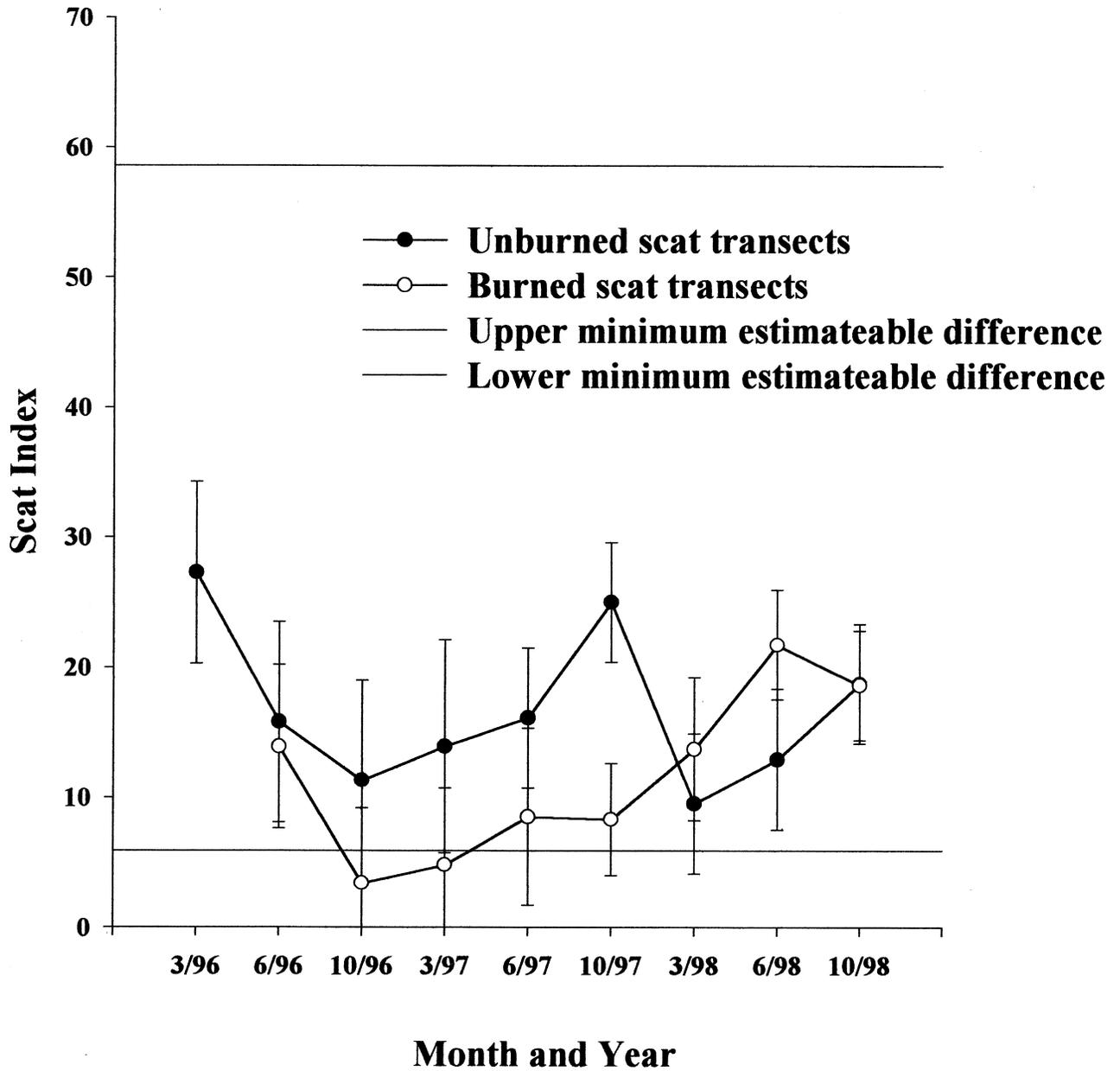


Figure 3. Gray fox scat indices determined in burned and unburned chaparral and forest on Four Peaks and Mt. Ord in the Mazatzal Mountains, Arizona, 1996-98. Note that the fire occurred between 3/96 and 6/96 samples. Scat index is determined from (# of scats/# of nights between collection) x 100.

### Coyote

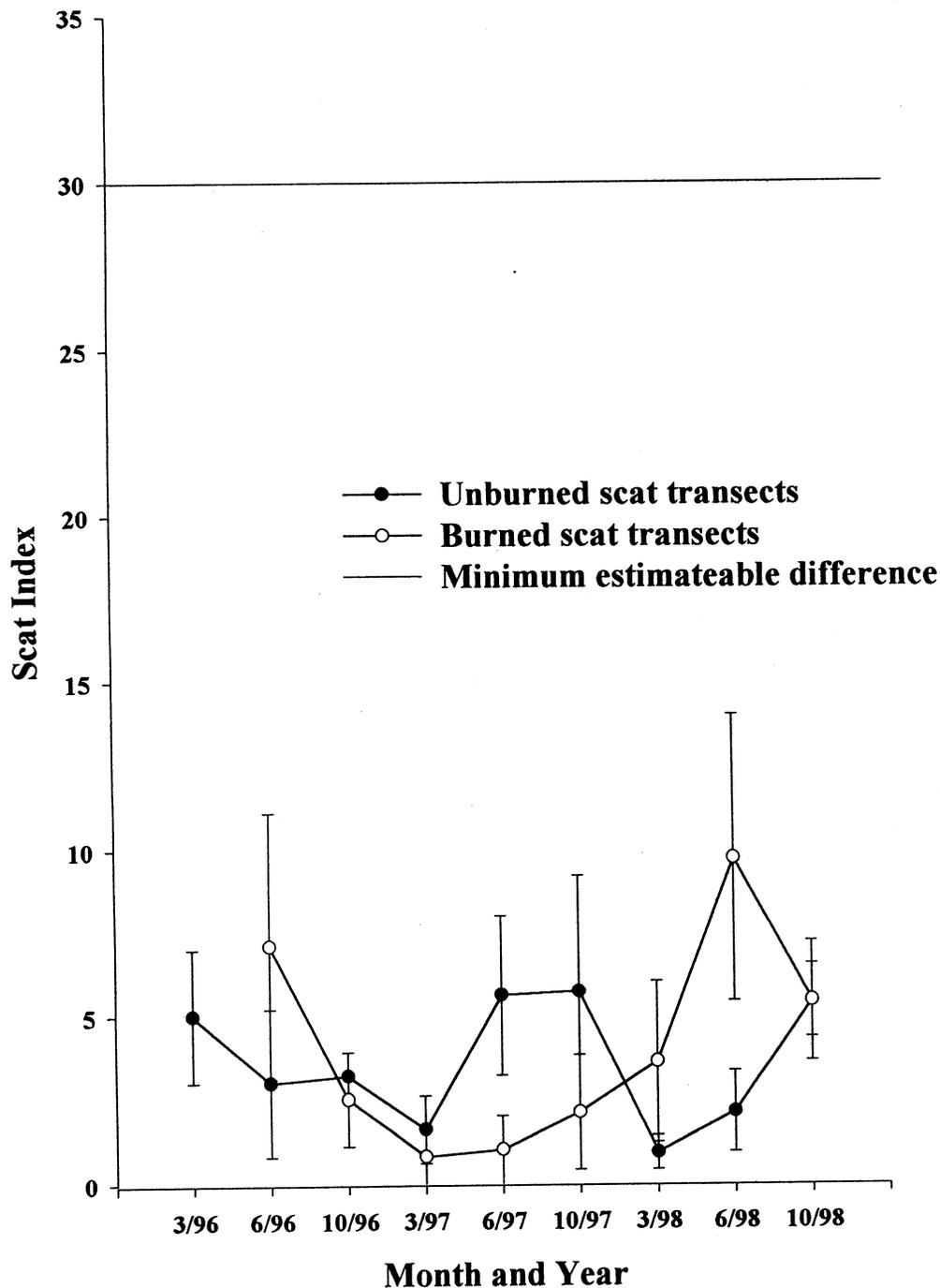


Figure 4. Coyote scat indices determined in burned and unburned chaparral and forest on Four Peaks and Mt. Ord in the Mazatzal Mountains, Arizona, 1996-98. Note that the fire occurred between 3/96 and 6/96 samples. Scat index is determined from (# of scats/# of nights between collection) x 100.

burned sites in 1996, as opposed to 19 within unburned areas.

The Lone Fire changed food availability for gray fox for at least 2 years. Prickly pear was the only mast species eaten in burned sites in 1997, and gray fox had to search to find fruits since prickly pear growth was slow post-fire (Boyd 2001). Manzanita and prickly pear, although common in chaparral communities, are considered fire intolerant (Patton and Gordon 1995), and animal ingestion and defecation are necessary for seed dispersal.

Gray fox diets vary among temperate zone locations and seasons, and fox are considered more omnivorous than other Canids (Fritzell 1987). Similar to our results, studies elsewhere reported that vertebrates are more important in winter, and insects and plant material more important in summer and fall (Wood et al. 1958, Fritzell 1987, Navaro et al. 1995). However, 2 gray fox diet studies in the Southwest found higher animal matter consumption than we did. In the Arizona Sonoran desert, Turkowski (1969) found that mammals and arthropods occurred twice as frequently as plants in gray fox diet. In Texas, Wood (1954) found that cottontails were 69% of gray fox diet, and plant material was only 11%. In our study, soft mast was able to meet gray fox nutritional requirements, as gray fox density increased with this diet.

Within burned sites, important coyote foods were rodents, manzanita, and juniper berries. In unburned areas, manzanita and juniper berries, rodents, and rabbits were the primary coyote foods (Appendix 4). Rabbits were conspicuously absent in coyote diets in burned areas, and no rabbits were found in the diet in burned or unburned areas in 1999. The presence of rodents increased in coyote diet when rabbits decreased in 1999. Coyote diets differed more among years and vegetation types than gray fox.

The use of deer was greatest in fall and winter (post-fawning) in both vegetation types, similar to other coyote food habits studies (MacCracken and Hansen 1987, Gese et al. 1988, Toweill and Anthony 1988). It is interesting to note that coyote consumption of deer did not increase in the burn, since mule deer (*Odocoileus hemionus*) preferred vegetation in the burn for feeding (Boyd 2001). Like gray fox, coyotes ate more mast in unburned than burned sites during breeding. Similar to this study, Barrett (1982) found that coyotes in a California chaparral community ate soft mast, primarily manzanita, most often in summer and fall. We concur with Andelt et al. (1987) that the coyote is an opportunistic predator, whose diet reflects changes in climatic patterns, prey vulnerability, plant phenology, and in this study, changes in plant succession due to fire.

Proportion of small mammals eaten by gray fox and coyotes was similar, which contrasts studies that found that gray fox were less carnivorous when sympatric with coyotes or bobcats (Scott 1955, Hockman and Chapman 1983, Major and Sherburne 1988). They inferred that spatial segregation and possible food competition could be responsible. Since gray fox were able to find and eat rabbits in burned sites, and coyotes did not, we doubt the presence of coyotes influenced gray fox carnivory.

We only collected an adequate bobcat scat sample size in 1998 ( $n = 30$ ). Rodents (46%) and rabbits (40%) made up the majority of the diet, and deer and birds both appeared in 13.3% of the scats. Cattle and raccoon (*Procyon lotor*) occurred in 3.3% of bobcat scats. There was no difference in diet between burned and unburned areas.

## BLACK BEAR POPULATION CHARACTERISTICS

Studies on the effect of fire on bears have either looked at effects immediately post-fire, or several years after the burn. Blanchard and Knight (1990) recorded 21 transmittered grizzly bear (*U. arctos horribilis*) reactions during and up to 6 months after a 1988 wildfire in Yellowstone National Park. Thirteen moved into burned areas after the fire front passed, 3 remained within the burn perimeter as the fire progressed, 3 stayed outside burned areas at all times, and 2 were believed to have died during the fire. Bears that moved into burned areas after the fire fed on fire-killed ungulate carcasses. In Alaska, Schwartz and Franzmann (1991) documented increased black bear cub production and survival in an area of a recent burn (<10 years) due to increased food supply, primarily moose (*Alces alces*) calves. Patton and Gordon (1995) found that black bears use recently (2-20 years) burned areas heavily in western United States forests, when berry producing plants are available.

The Lone Fire burned >90% of the black bear study area used by LeCount in the 1970s. In his 6-year black bear study in the Four Peaks area, LeCount (1982) estimated a stable density of 1 bear/3.0 km<sup>2</sup>, an equal sex ratio, and an average age of 8.1 years. Adult males had an average home range size of 29.0 km<sup>2</sup> and adult females 18.0 km<sup>2</sup>, with considerable home range overlap. He stated population density was regulated by habitat quality, nutrition, subadult dispersal, and cannibalism of younger bears by resident adults. In a pre-study black bear capture attempt in September - October 1996, we set 8 baited snares (142 snare nights) in locations used by LeCount and had no visits. Because we found little bear sign, and LeCount's density estimate was the highest documented in

Arizona, we initiated a study to see how the Lone Fire affected black bear density, sex and age ratios, survival rates, and reproduction. We compared demographic parameters within the burn perimeter with a population on an unburned sky island (Mt. Ord) during the same time period (1997-2000), and LeCount's (1982) data. LeCount et al. (1984) described Mt. Ord as excellent black bear habitat and determined some males from both Mt. Ord and Four Peaks visited both areas during breeding season.

The black bear population living within the burn perimeter had different population characteristics than black bears on Mt. Ord and was different from what LeCount found. LeCount (1982) documented 19 adult females living in an area where we documented only 7. Because of this reduction we found a 4:1 male:female ratio which was more skewed towards males than any we found in other black bear literature. Although females had cubs within the burn perimeter, none of the 16 cubs we found survived their first year. We believe the high male:female ratio increased black bear predation on cubs, as the increased density we documented in unburned islands would make it impossible for females with cubs to avoid males.

### Field Efforts and Analyses

1. LeCount et al. (1984) described their study area as 120 km<sup>2</sup> along the east side of the southern Mazatzal ridgeline from Apache Lake NE to Sycamore Canyon, which encompassed Four Peaks. Their study area is referred to in this document as the Four Peaks study area. For some analyses, we looked at black bears captured within the burn perimeter separately (Fig. 1).
2. We used Aldrich foot snares to capture black bears at baited sites and

- trail sets to determine sex and age ratios, and estimate population density. Sampling was conducted on snare lines on both sky islands. Snare locations within the burn perimeter were in unburned islands (12.2 km<sup>2</sup> area and 3 riparian drainages) to provide shelter for captured black bears.
3. Black bears captured in Aldrich foot snares were immobilized with Telazol (5.0 mg/kg), examined for injuries, sexed, and a premolar extracted to estimate age. Each individual was equipped with a numbered plastic tag in each ear.
  4. All adult females captured and random adult males ( $n = 25$ ) were fitted with radio collars. Aerial radio tracking flights occurred every 7-10 days from April 16 -November 1 and bimonthly tracking flights were made during denning (November 2 - April 15). Flights were made during the first 2 hours of daylight so locations primarily indicated early morning feeding areas.
  5. We analyzed black bear sex and age data with a Mann-Whitney *U* test and a Chi-square test. Three population estimates were determined using a Petersen Index, Leslie Index, and a modified Petersen Index (Garshelis 1992). Density was determined by dividing the number of bears by the size of the study area. Within the burn perimeter, we estimated density by dividing the population by the amount of unburned vegetation (44 km<sup>2</sup>). We determined the reproductive activity of all radiotransmitted females by visiting dens and/or checking reproductive condition during subsequent recaptures.
  6. Survival rates on transmitted black bears were determined using the Kaplan-Meier staggered entry design (Pollock et al. 1989). Cub survival was determined by visiting dens; cubs were considered dead if they did not appear as yearlings with the female the following year.
  7. Size of the burned area and unburned islands were determined using an ARC-INFO GIS Landsat Thematic Mapper image taken May 16, 1996, just after the Lone Fire. The amount of each vegetation type within study areas was determined from an Arizona GAP vegetation map (Halvorson and Kunzmann 2000).

### Effects on Black Bear Demography

*Capture* - Within the Four Peaks study area we captured 38 black bears (>1-year old) 87 times in 1,134 trap nights with 48 recaptures (capture success = 7.7%). Thirty-one of these were captured 71 times in 889 nights (8.0%) within the burn perimeter. On Mt. Ord, we captured 16 individuals 23 times in 207 trap nights (11.1%).

*Sex ratio* - The sex ratio of captured black bears >1-year old within the burn (4M:1F) was significantly different from a 1:1 sex ratio. On Mt. Ord we captured more males, but the sex ratio (1.7M:1F) was not statistically different. Within the burn we captured from 3-8 new, unmarked males each year from 1997-2000. With females, however, we captured 4 adult females in 1997, 1 new female in 1998, and no more in the next 2 years (461 more trap nights).

*Age Structure* - Subadults comprised 20% of captured black bears on both the Four Peaks study area and Mt. Ord. Mean age of males on Four Peaks was 7.9 years

(SE = 1.0) and females was 5.2 (SE = 1.1). Both sexes had virtually the same mean age (5.4 and 5.5 years) on Mt. Ord. Although no black bear captured on Mt. Ord was aged >10- years old, 8 of 23 males in the Four Peaks area were.

*Reproduction* - Of 4 breeding-aged female black bears captured in the Four Peaks study area in 1997, none showed signs of having cubs. All 4 produced at least 2 cubs (1 litter of 3) in the winter of 1997-98. Two of 5 female black bears located within the burn perimeter had cubs (2 and 3) in 1998-99. The other 3 females were barren, without yearlings present, and changed dens frequently. In the winter of 1999-2000, we checked 3 denning females, and only 1 had cubs. Litter size in the burn perimeter averaged 2.3, and 16 cubs were born in 3 years.

Similar to Four Peaks, none of the 4 female breeding-age black bears captured on Mt. Ord in 1997 showed signs of reproduction. Three of 4 females produced 6 cubs in winter of 1997-98. In winter 1998-99, 2 of 3 females had 5 cubs; the other had 1 yearling. In the winter of 1999-2000, 1 female had 2 cubs, and the other 2 females had yearlings with them. Average litter size was 2.2, and 13 cubs were born from 1997-1999.

*Survival/Mortality* - All 16 known cubs born within the burn perimeter died in their first year. We captured 3 yearlings (2 males and 1 female) within the burn perimeter, but they were not associated with marked females and probably not born there. Cub survival on Mt. Ord was 4 of 11 known born.

Overall, 9 of 52 (17%) black bears >1 year old died from 1997-2000 (4.3%/year). The primary cause of adult mortality during this study was legal hunting (77.7%). In the Four Peaks study area, a 4-year old female and 4 males from 3 to 7-years old were killed by hunters on or near the study area.

Two males captured on Mt. Ord were killed by hunters. Other causes of marked adult mortality include 1 13-year old male killed in an automobile collision, and 1 5-year old female believed killed and eaten by another black bear.

Using the Kaplan-Meier method, females had an overall survival rate of  $0.92 \pm 0.10$  (35.5 bear years), and the mean annual female survival rate was  $0.98 \pm 0.02$ . Males had an overall survival in 36.4 bear years of  $0.77 \pm 0.14$  with a mean annual survival of  $0.94 \pm 0.03$ .

*Density* - LeCount (1982) estimated 40 bears in his study area; we captured 28 males and 10 females there and estimated 63 bears. So, even after the fire there were probably more bears in the area than when LeCount (1982) worked there. Aerial locations found black bears primarily (90.1%) in green islands within the burn perimeter, and density estimates ranged from 1 bear/0.6-1.4 km<sup>2</sup> (Table 3) in these areas. Density estimates on Mt. Ord ranged from 1 bear/3.3-6.6 km<sup>2</sup>.

*Comparison from within the burn perimeter, Mt Ord, and LeCount's findings* - The sex ratio of adult black bears within the burn was skewed more towards males than other black bear studies in the Southwest (Waddell and Brown 1984, LeCount and Yarchin 1990, Doan-Crider and Hellgren 1996). LeCount (1982) captured 19 adult females in an area where we only captured 7. Male bias in trap samples is often attributed to larger home range sizes (Jonkel and Cowan 1971, Lindzey and Meslow 1977). However, because no unmarked females were captured in our continued trapping effort within the burn perimeter after June 8, 1998, a large drop in the female population is indicated.

The proportion of subadults and mean ages was similar to that found 20 years earlier by LeCount (1982). A 20% subadult capture is indicative of a lightly exploited

Table 3. Population estimates of adult (>2 years) black bears in both study areas of the Mazatzal Mountains, Arizona, 1973-2000. Density estimates includes subadults (calculated separately).

Study area (km <sup>2</sup> )	Population estimate <sup>a</sup>	Number of bears marked in area	Density estimate (1 bear/x km <sup>2</sup> )
Estimation method			
Four Peaks, 1973-1978 (LeCount 1982: 120 km <sup>2</sup> )			
Leslie method	32	28	3.4 km <sup>2</sup>
Petersen estimate	32 (+16)		
Four Peaks, 1997-2000 (this study: 105 km <sup>2</sup> )			
Leslie method	27 (+20)	30	3.2 km <sup>2</sup> (0.8) <sup>b</sup>
Petersen estimate	36 (+18)		2.5 km <sup>2</sup> (0.6)
Modified Petersen	16		5.2 km <sup>2</sup> (1.4)
Mt. Ord, 1997-2000 (this study; 120 km <sup>2</sup> )			
1997-1998			
Leslie method	21 (+11)	15	4.8 km <sup>2</sup>
Petersen estimate	30 (+23)		3.3 km <sup>2</sup>
Modified Petersen	15		6.6 km <sup>2</sup>

<sup>a</sup> 95% Confidence intervals in parentheses.

<sup>b</sup> ( ) = population estimate/26.2 km<sup>2</sup> (amount of unburned vegetation).

population with respect to hunting (LeCount 1982, Beechum 1983, Kolenosky 1986). It also may be indicative of low recruitment in the population before and during the study (Doan-Crider and Hellgren 1996).

Although black bear density was abnormally high within the burn, females were able to produce cubs, indicating adequate food conditions and nutrition (Rogers 1976, LeCount 1982, Schwartz and Franzmann 1991). The number of cubs produced/female during the study was equal between Mt. Ord and the Four Peaks study area (1.3 cubs/female). LeCount (1982) only found a 1 cub/female ratio over his 6-

year study, indicating the Lone Fire did not reduce cub productivity.

We suspect black bear predation on cubs was the primary cause of cub mortality. Increased predation on cubs could be the result of the high proportion of males in the limited size unburned islands. This probably made it impossible for females to avoid males spatially by using higher elevations as LeCount et al. (1984) found.

LeCount (1982) estimated cub survival at 48%; Mt. Ord estimates were slightly lower (38.5%). From black bear literature, cub survival estimates throughout North America ranged from 48 - 83%. Sorenson and Powell (1998) estimated 60% cub

survival for a black bear population in the southern Appalachians to remain stable. Carrel (1994) estimated 62% survival rate in Arizona for stability.

Lack of black bear recruitment for 4 years indicates the Lone Fire had a negative effect on the local black bear population, at least in the short term. Immigration from surrounding areas was documented for subadults and adults, all but 1 were male. We believe larger home range size of adult males and dispersal behavior of subadult males will continue to bring males to this area. However, if the regrowth of vegetation does not provide black bears cover requirements for reproduction and cub survival, the female portion of the population could be permanently reduced. Female replacement is rarely from immigration of subadult females since few disperse from their mother's home range (Rogers 1987, Schwartz and Franzmann 1992). Given fire frequency history in chaparral, we suspect vegetation will return to its original state. However, the loss of >90% of the coniferous forest could have a longer lasting effect as the ponderosa pine and spruce-fir may be replaced by a mixture of oak and chaparral.

Adult survival in both study areas was as great (95.7%) or greater than documented throughout North America. Legal hunting was the greatest mortality cause, but did not threaten the population status. Since 4 of 6 known hunter kills were ear tagged individuals, and not transmittered, the number of hunter kills was easier to determine than other sources of mortality. The odds of finding a black bear predation or injury related mortality on an ear tagged black bear are very low, but hunters usually turn in ear tags. It is possible mortality from all sources could be underestimated, and the proportion of all mortalities as hunter kills could be overestimated.

Arizona manages black bear hunting on a geographical unit basis, with a kill quota of females set for each unit, and when that number of females has been killed the unit is closed. Strategic plans call for no more than 5% of females harvested in a year. Given the small proportion of marked black bears (7 of 51; 13.7%) that were killed in a 4-year period, hunting under normal circumstances should not harm this population. However, since the female population may have been reduced from 19 to 7, and 1 of these females was killed in 2000, hunting may slow female recruitment.

The high density inside the burn perimeter was more similar to black bear densities documented in the eastern hardwood forests than in the southwestern United States and in the top 10% of black bear densities recorded (Beck 1991). The increase in density over the 1 bear/3.0 km<sup>2</sup> documented in the late 1970s probably severely reduced cub survivorship.

### **BLACK BEAR HOME RANGE, HABITAT USE, AND FOOD HABITS**

Black bear home range size is strongly affected by the abundance and spatial distribution of food (Mollohan 1987, Elowe and Dodge 1989, Schwartz and Franzmann 1991, Samson and Huot 1998). Food quantity and nutritional quality are believed to influence growth, age at first reproduction, interbirth intervals, litter sizes, survival of cubs and yearlings, and therefore population growth (Jonkel and Cowan 1971, Rogers 1976, Eiler et al. 1989, Schwartz and Franzmann 1991, Samson and Huot 1995). Consequently, environmental disturbances that effect mast quantities can affect black bear reproduction and survival (Kasbohm et al. 1996).

Arizona black bears typically prefer slopes >20% and areas with high horizontal cover between 0-2 m within chaparral,

woodland, or forest habitats (LeCount et al. 1984, Mollohan 1987, LeCount and Yarchin 1990). LeCount and Yarchin (1990) found that black bears in the White Mountains of eastern Arizona preferred to use areas in mixed conifer forests with dense (>60%) canopies. Large tree (>64 cm diameter at breast height - dbh) density on steep slopes (>20%) was important for bedding habitat. On Four Peaks, LeCount et al. (1984) found that males used lower elevations than females and hypothesized females used higher elevations to avoid black bear predation on their cubs. Maintenance of large trees (primarily conifers) in adequate densities for bedding and cub protection was recommended.

LeCount et al. (1984) found 21 plant and 10 animal foods were consumed by black bears in the Four Peaks area. Manzanita, grass, oak, prickly pear, juniper, and pigeonberry (*Rhamnus californica*) were most important. Mollohan (1987) found that plant species included grass, squawroot (*Conopholis mexicana*), oak, raspberry (*Rubus strigosus*), juniper, and manzanita; as were colonial insects such as ants and termites were important foods for black bears along the Mogollon Rim. The quantity and quality of manzanita, pigeonberry, juniper, and oak would all be negatively affected by a wildfire, at least initially.

Objectives of this black bear study segment were to document habitat characteristics selected by bears in the area of the burn, and compare them to characteristics selected on Mt. Ord and characteristics selected 20 years earlier on Four Peaks (LeCount et al. 1984). We used logistic regression to determine the most important variables selected on an unburned sky island (Mt. Ord) and tested this model with data collected within the burn to see if selection was similar. Since food availability is so important to black bears,

we documented food availability and food selection in both burned and unburned areas.

We found that black bears within the burn perimeter were primarily restricted to the unburned islands, and used similar vegetation cover for bedding and feeding as black bears on Mt. Ord. Black bears selected areas with both high horizontal and vertical cover, and the number of shrubs >1.2 m tall was the most consistent predictor of black bear habitat use. Black bear diet was similar between the burn and Mt. Ord, but black bears within the burn consumed grass more often than bears on Mt. Ord.

### Field Efforts and Analyses

1. Black bear locations were obtained during aerial radio tracking flights and used to delineate vegetation condition use patterns and estimate home range size (Minimum convex polygon, Mohr 1947).
2. We tracked transmitted black bears from the ground and either visually observed or circled the bear within 200 m (LeCount and Yarchin 1990). The site was marked and revisited within 3 days. If we did not observe the animal, we searched for beds or scat to ensure the accuracy of location. We measured vegetation and topographic characteristics at summer daytime (>2 hrs post sunrise <2 hrs pre sundown) use sites from July 15 - September 30 from 1997-1999.
3. A bed site or black bear sign was used as the center of a vegetation inventory (LeCount and Yarchin 1990) from which we ran 25-m line-intercept vegetation transect oriented to the contour. Vegetation cover was measured at different height intervals as described earlier (See Lizard Field

Efforts). Canopy cover directly over the black bear sign was measured with a spherical densiometer and the following cover classes were used: 0%, 1-10%, 11-25%, 26-50%, 51-75%, >75%. Horizontal visibility was measured as the distance (m) from the sign at which 90% of an average size black bear would be hidden from view, in each of the 4 cardinal directions, and distances averaged (LeCount et al. 1984). Slope and general topographic type (ridgeline, talus slope, canyon bottom, foothills, and bajada) were also recorded. Black bear forage plants (as identified by LeCount et al. 1984) within a 10-m radius (0.04 ha total area) of the sign were recorded and phenologically described according to West and Wein (1971). We counted the number of shrubs >1.2 m tall, coniferous trees, and deciduous trees in the same 0.04 ha plot.

4. We defined and measured black bear habitat selection as the disproportionate use of habitats relative to availability in burned and unburned areas (Johnson 1980, North and Reynolds 1996). We estimated availability with GIS generated random sites within the study area (Marcum and Loftsgaarden 1980), and measured 2 random sites for each black bear site measured. We used log-likelihood  $X^2$  tests of independence and Mann-Whitney  $U$  tests to assess differences in habitat variables between used and random sites. We calculated Bonferroni confidence intervals (Neu et al. 1974) to estimate whether black bears selected or avoided the burn when choosing daytime sites. We used

logistic regression to build models that best predicted black bear daytime site selection.

5. Black bear scats were collected at capture and random locations. Scat samples and food habits data were analyzed using procedures described in Carnivore field efforts.

### Effects on Home Range Size

Home range size of female black bears captured in the burn differed among years, with long-range movements in 2000 resulting in significantly larger home range sizes (Fig.5). Female black bear home range size did not differ 1997-1999 and ranged from 11-15 km<sup>2</sup>, with a high degree of female home range overlap. The large mean home range size in 2000 (125.3 km<sup>2</sup>) was due to movements to lower elevations and up to 29 km movements northeast to the Sierra Anchas Mountains. Males in the Four Peaks study area had a larger overall home range than females, and home range size was similar among years. There were no significant differences between males and females in annual home range size on Mt. Ord (Fig. 6). Home range overlap was not as great as on Four Peaks. Males captured in the burn had larger mean home range sizes than males captured on Mt. Ord (115 km<sup>2</sup> vs. 35 km<sup>2</sup>); female home range sizes were similar (14.4 km<sup>2</sup> vs. 17.4 km<sup>2</sup>).

Home range size of female black bears captured within the burn from 1997-1999 was only slightly smaller than LeCount (1982) found. The much larger home range size in 2000 was probably due to a lack of food caused by drought, not the fire, causing females to make long-range movements to lower elevations and other mountain ranges. Each female returned to their original home range; these types of movements are not uncommon during food shortages (Schwartz and Franzmann 1991, Samson and Huot

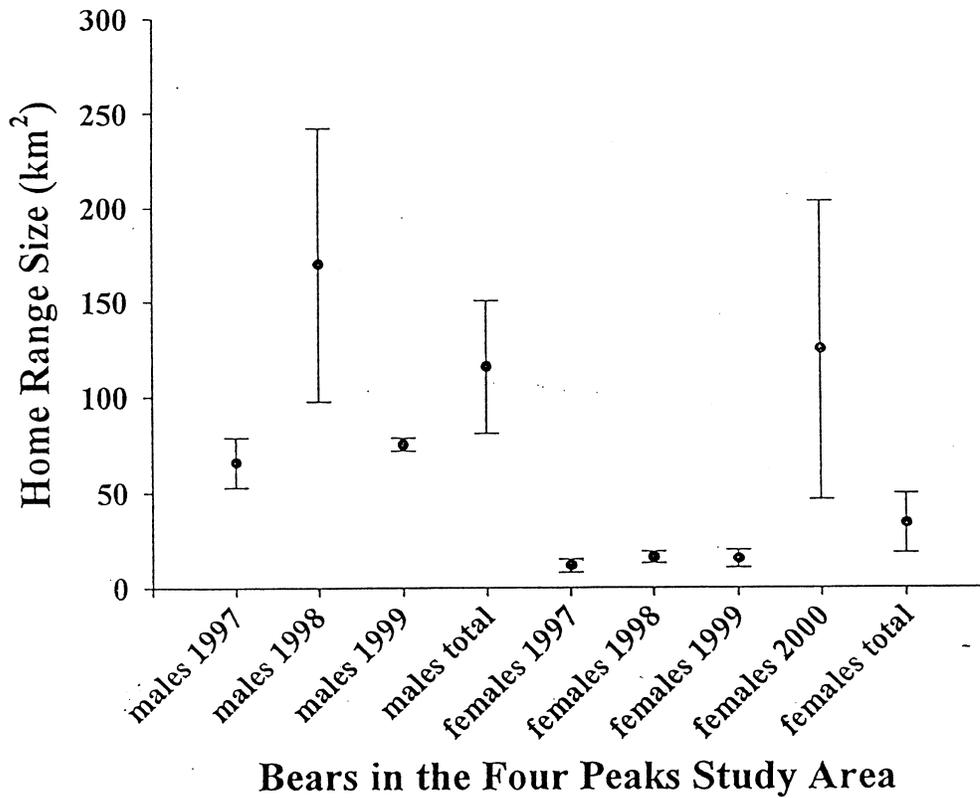


Figure 5. Annual and overall home range size of male and female black bears captured in the Four Peaks study area in the Mazatzal Mountains, Arizona, 1997-2000. There was insufficient data to compute mean male home range size in 2000.

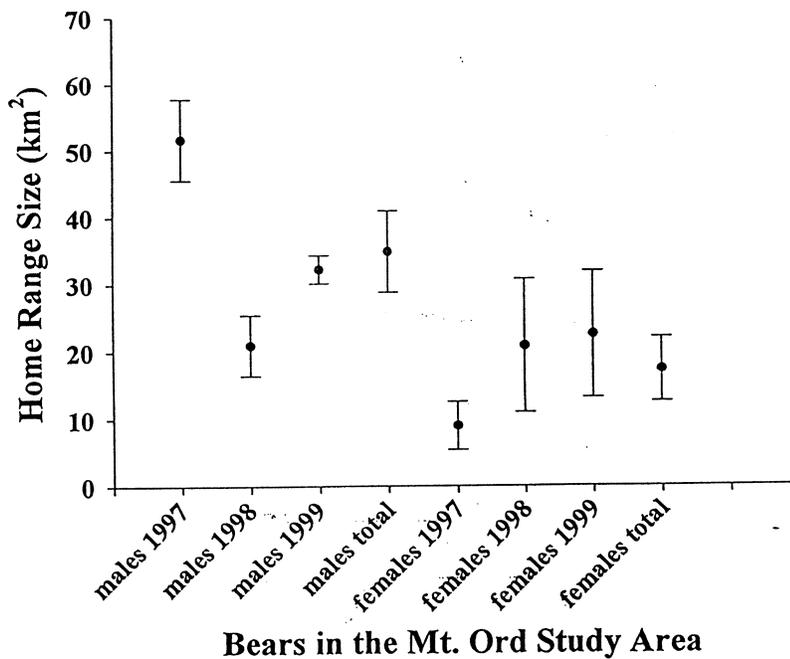


Figure 6. Annual and overall home range size of male and female black bears captured in the Mt. Ord study area in the Mazatzal Mountains, Arizona, 1997-99.

1998). Larger home range sizes for males captured in the burn as compared to Mt. Ord may be due to effects of the fire. Males may have been looking for females for breeding that were displaced or killed as a result of fire, or they had to travel further to find food.

### Effects on Habitat Use

*Use of burned vegetation* - Male and female black bears preferred to use daytime feeding and bedding sites within unburned islands in the burn perimeter, only 8 (10%) of 81 daytime locations occurred in burned vegetation.

In early morning aerial locations, female black bears were found more often in unburned “islands” of vegetation within the burn perimeter than males. Transmitted females were found in islands in similar proportions in 1997 (82.4%) and 1998 (80.3%), but less in 1999 (65.2%). Males were found in unburned islands 58.6% in 1997 and 57.6% in 1998. In 1999, transmitted males were located more in burned vegetation (67.5%).

Of 5 collared females captured in the burn, 2 denned in an unburned island each year, and 2 denned in burned vegetation each year. In 1997, the proportion of early morning locations in burned vegetation between females that denned in burned vegetation versus those that denned in unburned vegetation was almost equal (19% and 16.2% respectively). However, in 1998 and 1999, early morning locations of the 2 females that denned in burned areas were in burned areas more than those that denned in unburned areas (1998 - 45.5% vs. 15.6%, 1999 - 42.3% vs. 32%).

*Vegetation cover* - As expected in burned areas, horizontal cover, vegetation cover between 0-1.8 m, and the number of shrubs >1.2 m tall significantly increased over the study, but numbers of deciduous or coniferous trees, or cover >1.8 m did not

increase. There was still a significant difference between vegetation cover in 1999 random sites, cover LeCount documented, and what we found black bears selected (Fig. 7).

Because black bears on Four Peaks almost completely avoided burned vegetation for daytime locations, most vegetation categories were significantly different between black bear and random locations (Table 4). Horizontal cover was 3 times greater at black bear microsites than random sites, and vertical cover was >75% over 60% of the time (Fig. 8). On Mt. Ord, horizontal cover and vertical cover from 0.91 m to >4.6 m were significantly different (Table 5). Horizontal cover was twice as great at black bear sites as at random Mt. Ord locations and vertical cover was >75% canopy cover 66.6% of the time.

Shrubs >1.2 m tall were almost 6 times more numerous at black bear locations than random locations in unburned or burned vegetation (Fig. 9). The number of deciduous trees was also significantly higher than random locations. Black bear locations on Four Peaks had less coniferous trees/0.04 ha than bear or random locations on Mt. Ord.

*Predicting habitat use* - We developed a logistic regression model to predict black bear habitat use with data gathered on Mt. Ord. Shrub cover (number of shrubs >1.2 m tall) was the greatest predictor (Table 6). When this model was applied to black bear and random sites on Four Peaks, it correctly classified 50/65 (77%) black bear sites and 116/137 (85%) of random sites. The next highest ranked model included number of shrubs and horizontal cover.

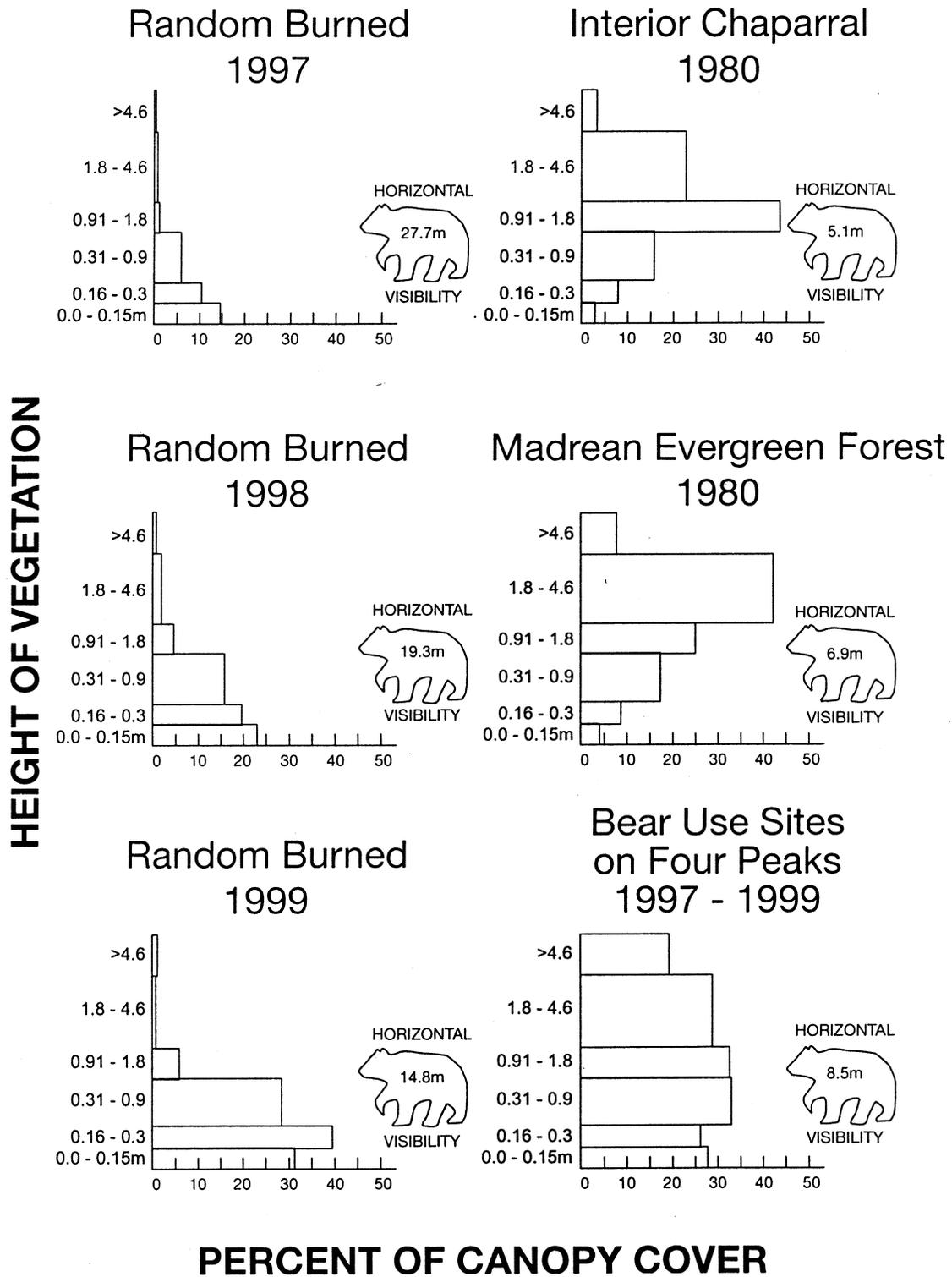


Figure 7. Mean vegetation cover by height interval and horizontal visibility measured at random locations within the Lone Fire burn perimeter from 1997-99, and black bear locations within the burn perimeter 1997-99, and recorded by LeCount et al. (1984) in the Four Peaks study area, Mazatzal Mountains, Arizona.

Table 4. Comparison of habitat variables measured at black bear day-sites and random plots on the Four Peaks study area, Mazatzal Mountains, Arizona, 1997-99.

Variable	Bear location		Random location		<i>P</i>
	$\bar{x}$	SE	$\bar{x}$	SE	
Food availability (number of food plants/0.04 ha)	4.3	0.3	1.5	0.1	<0.001
Horizontal cover (m/0.04 ha)	8.5	0.6	22.0	1.5	<0.001
Number of coniferous trees (0.04 ha)	3.1	0.7	1.3	0.3	0.001
Number of deciduous trees (0.04 ha)	9.3	1.3	1.1	0.2	<0.001
Number of shrubs (0.04 ha)	27.2	2.4	6.1	0.5	<0.001
Percent slope	27.0	1.9	18.7	1.5	<0.001
Percent cover 0 to 0.15 m	27.9	2.5	21.4	1.3	0.168
Percent cover 0.16 to 0.30 m	26.6	2.6	17.9	1.3	0.240
Percent cover 0.31 to 0.90 m	33.7	2.6	13.5	1.3	<0.001
Percent cover 0.91 to 1.80 m	32.1	2.5	4.6	0.9	<0.001
Percent cover 1.81 to 4.60 m	29.0	2.9	3.1	0.8	<0.001
Percent cover >4.61 m	19.4	2.9	1.9	0.6	<0.001

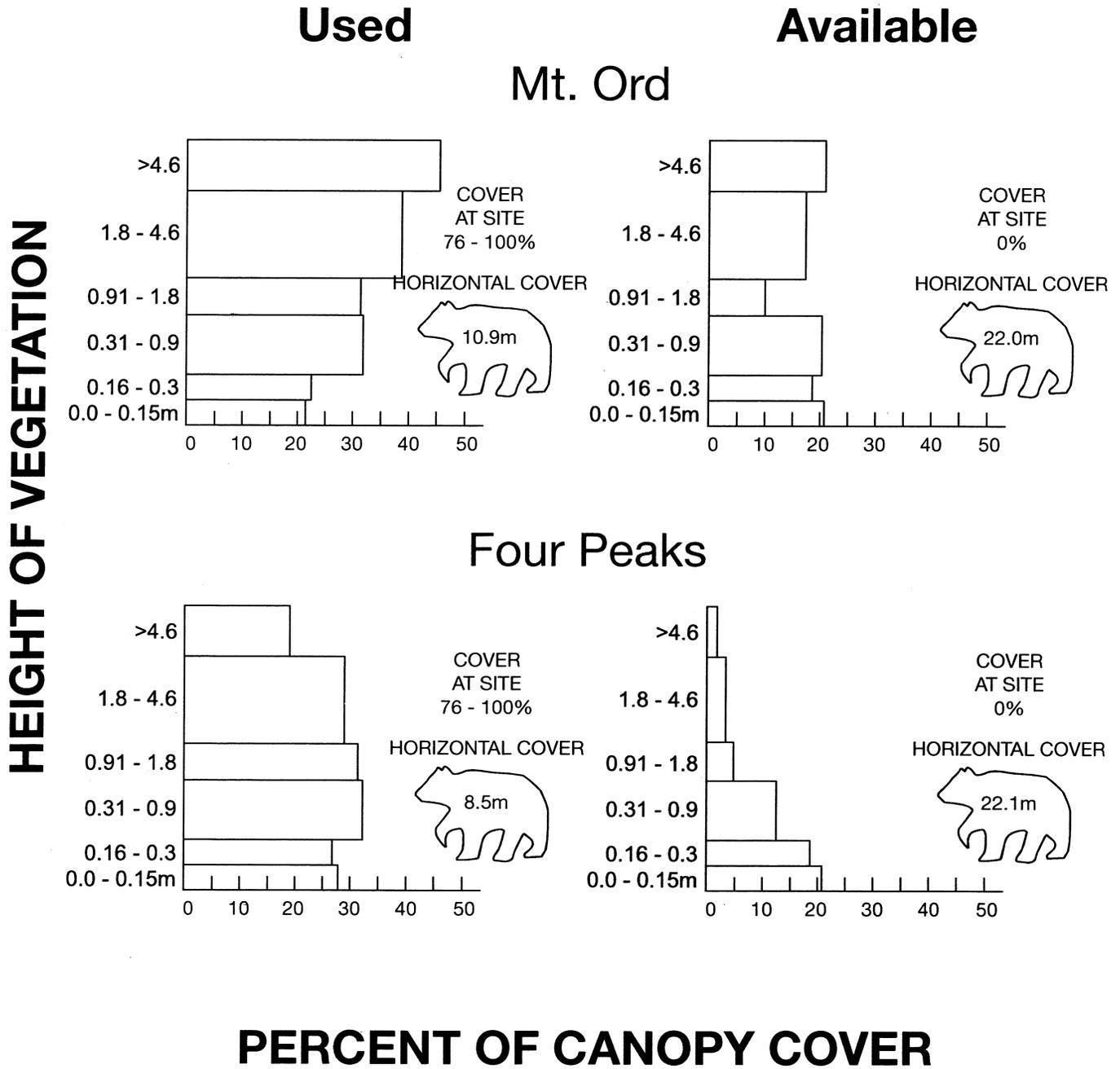


Figure 8. Comparison of mean vegetation cover by height interval, horizontal cover, and canopy cover between black bear locations on Mt. Ord, Four Peaks, and random locations in burned and unburned sites in the Mazatzal Mountains, Arizona, 1997-99.

Table 5. Comparison of habitat variables measured at black bear bed-sites and random plots on the Mount Ord study area, Mazatzal Mountains, Arizona, 1997-99.

Variable	Bear location		Random location		P
	$\bar{x}$	SE	$\bar{x}$	SE	
Food availability (number of food plants/0.04 ha)	5.9	0.5	3.5	0.24	<0.001
Horizontal cover (m/0.04 ha)	10.9	1.3	21.9	2.2	0.001
Number of coniferous trees (0.04 ha)	9.2	2.7	12.2	1.9	0.614
Number of deciduous trees (0.04 ha)	11.7	3.0	5.4	0.9	0.031
Number of shrubs (0.04 ha)	29.3	4.1	6.8	1.1	<0.001
Percent slope	42.3	6.2	20.4	1.7	0.001
Percent cover 0 to 0.15 m	22.4	3.9	21.1	2.6	0.482
Percent cover 0.16 to 0.30 m	23.7	3.9	18.7	2.3	0.168
Percent cover 0.31 to 0.90 m	32.7	4.9	20.8	2.7	0.210
Percent cover 0.91 to 1.80 m	32.0	4.1	9.9	1.6	<0.001
Percent cover 1.81 to 4.60 m	38.9	5.3	16.9	2.4	<0.001
Percent cover >4.61 m	45.2	6.3	21.6	3.5	0.002

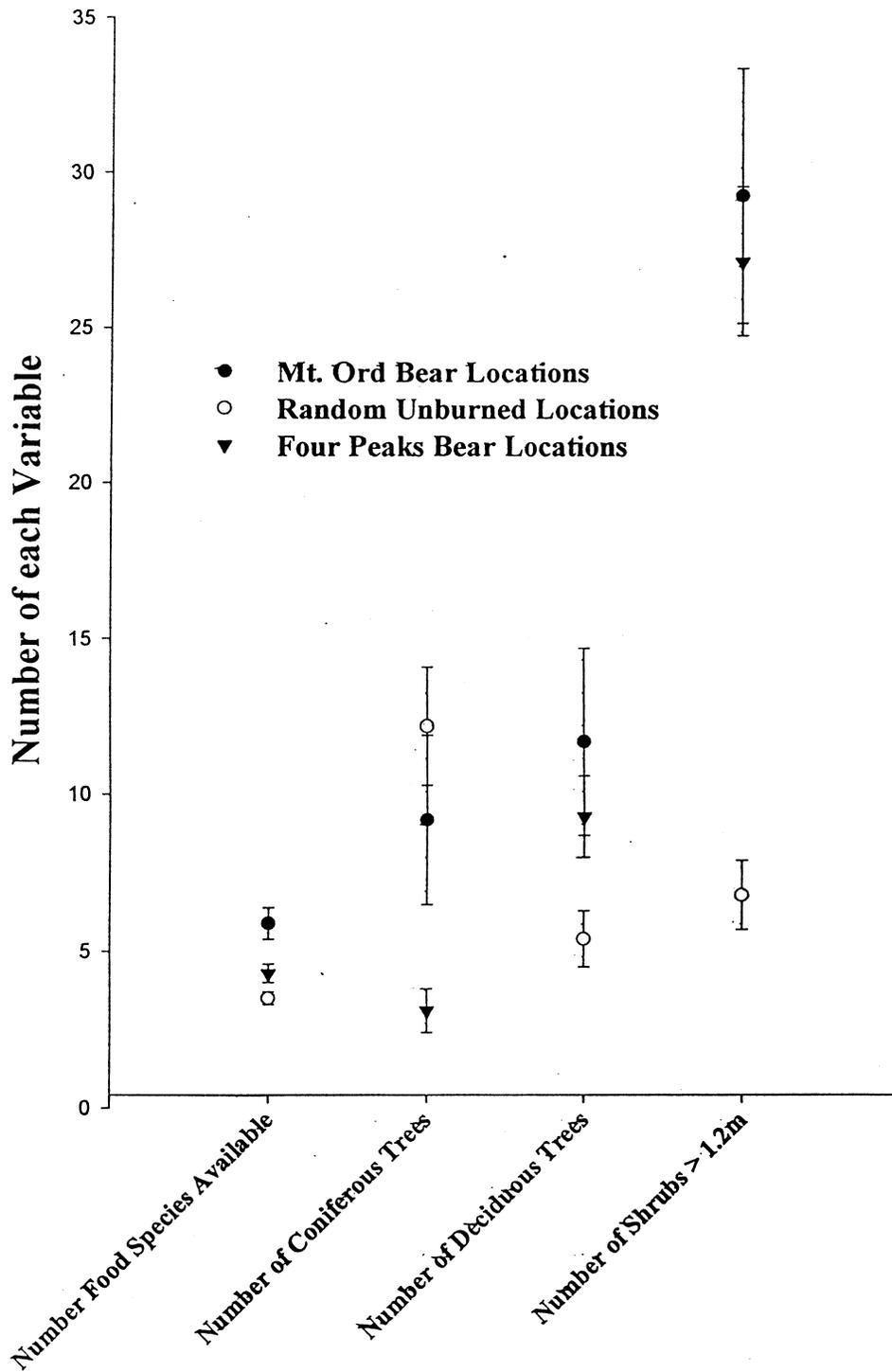


Figure 9. Comparison of number of food species available, number of coniferous trees/0.04 ha, number of deciduous trees/0.04 ha, and number of shrubs >1.2 m tall/0.04 ha between black bear locations on Mt. Ord and Four Peaks, and random locations in unburned sites in the Mazatzal Mountains, Arizona, 1997-99.

Table 6. Ranking of logistic regression models to predict black bear microsites on Mt. Ord, Mazatzal Mountains, Arizona, 1997-99. Models are presented in order of parsimony.

MODEL	- 2 LOG LIKELIHOOD	% bears correctly classified	% randoms correctly classified	AICc
1	73.653	76	86	3.134
2	73.122	76	83	9.435
3	70.937	76	87	18.505
4	56.262	83	85	24.731
5	52.584	83	89	34.294
6	47.693	88	92	45.014
7	44.463	79	93	56.589

- 1 Number of shrubs only
- 2 Number of shrubs and horizontal cover
- 3 Number of shrubs, horizontal cover, and vegetation cover in the 0.91-1.8 m category
- 4 Number of shrubs, horizontal cover, vegetation cover in the 0.91 – 1.8 m category, and slope
- 5 Number of shrubs, horizontal cover, vegetation cover in the 0.91 – 1.8 m category, slope, and number of foods available
- 6 Number of shrubs, horizontal cover, vegetation cover in the 0.91 – 1.8 m category, slope, number of foods available, and vegetation in the 0.31 – 0.9 m category
- 7 Number of shrubs, horizontal cover, vegetation cover in the 0.91 – 1.8 m category, slope, number of foods available, vegetation in the 0.31 – 0.9 m category, and percent cover at the center of the site

*Topography* - Black bears on both Mt. Ord and within the burn perimeter preferred talus slopes and canyon bottoms and avoided ridgetops and foothills. Mean slope use by black bears on Mt Ord was 42.3% and was 20.6% in the burn.

*Comparison of habitat use between the burn and Mt. Ord* - The majority of our locations were found in unburned islands within the burn perimeter, and black bear habitat selection in these areas was similar to vegetation and topography selected on Mt. Ord. Therefore, we assume effects of the Lone Fire would have been worse if the fire had not left islands of unburned habitat. If the diversity of vegetation with both forest and chaparral had not been left, we believe the number of resident females could have further declined. Without shrub cover, Mollohan (1987) observed black bears

avoided ponderosa pine with little horizontal cover from 0-2 m.

After 4 growing seasons, even in fire-adapted chaparral, regrowth was inadequate to provide preferred black bear vegetation cover and food resources, and most vegetation characteristics were significantly less than what bears selected. However, both male and female locations within burned vegetation increased yearly. We suspect as shrub growth continues, and the number of shrubs >1.2 m tall increases, black bears will find more area adequate to meet food and cover requirements. We doubt cub survival will be close to normal (50 to 65%) until vegetation reestablishes and black bear density again approximates 1 bear/3.0 km<sup>2</sup>. The loss of ponderosa pine could continue to affect cub survival, as LeCount and Yarchin (1990) found large trees were good cub escape cover. They also

documented that black bears avoided areas of clear cutting (leaving similar barren vegetation) for up to 30 years.

A continued male dominated sex ratio will continue to affect cub survival since males are the primary predators of cubs (LeCount 1987). Limited female migration from their natal territory (Schwartz and Franzmann 1992), coupled with no to low cub survival, prompts concern that even as vegetation returns to normal, the female portion of the population may have a difficult time replacing itself. However, as vegetation returns to prefire conditions, females should be able to move out of the unburned islands, and spatially avoid males as LeCount et al. (1984) documented.

The forested island on Four Peaks was reduced in size from 51.0 km<sup>2</sup> to just 2.2 km<sup>2</sup> of ponderosa pine and 11.9 km<sup>2</sup> of Madrean evergreen woodland. We never observed ponderosa pine reproduction, and after this severe a fire, the pines may never return (Swetnam et al. 1999). We did document resprouting and reproduction of Gambel's and Emory oak. Unsworth et al. (1989) and Young (1984) both reported use of timbered areas for bedding. Since black bears depend on large trees for bedding, food, and cub survival; deciduous tree reproduction alone may not be adequate to sustain the cub survival documented by LeCount (1982) or on Mt. Ord.

### Effects on Black Bear Diet

Number of food plants available at black bear sites was greater on Mt. Ord (5.9) than random plots (3.5), and Four Peaks (4.3 vs.1.5). However, presence or absence of the 2 key food species, oak or manzanita, did not predict black bear distribution.

We analyzed 245 scats ( $n = 91$  burned;  $n = 154$  unburned) from 1997 through 1999 and found 11 plant and 8 animal food items were consumed. Frequency of occurrence of grass was greatest in burned vegetation

(Appendix 5) and soft mast (berries and fruits) was greatest in unburned vegetation. Of all soft mast food items consumed, manzanita was most common in both vegetation types. One-seed juniper was consumed more in unburned sites than burned. Oak acorns were the only hard mast food item eaten. Animal matter (primarily insects) was always eaten in lower proportions than plant material in both burned and unburned sites.

Grasses were eaten most in all years (>50.0%) in burned sites. In unburned vegetation, the most consumed food item varied among years (Appendix 6); serviceberry was eaten most in 1997, grasses in 1998, and one-seed juniper in 1999. Acorns were eaten more in burned sites in 1997 and 1998, but were not found in any scats in 1999. Similarly, acorn use in unburned sites was lowest in 1999. All food niche overlaps were high (>100%).

Within the burn perimeter, the proportion of acorns and manzanita berries increased each year. In 1997, 14% of oak plants in random locations had acorns, in 1998 15.6% had acorns, and in 1999 72.3% of oak plants produced acorns. In 1997, 10% of manzanita plants in random plots had fruit, 18.8% in 1998, and 54.5% in 1999.

Black bear diets on Four Peaks and Mt. Ord sky islands were high in plant material and low in animal matter, which is consistent with other studies in Arizona. Burned and unburned sites had high overlap in the amount of each species eaten, except grass and acorns. We suspect black bears within the burn fed in unburned islands, hence the similarity of diets. Still, insects, newly emerged grasses, ants, and quick successional species (oaks) are food items that increase as an immediate effect of fire (Blanchard and Knight 1990), and black bears used these items slightly more in burned areas. We never found prickly pear

used at the same frequency as LeCount et al. (1984).

## SUMMARY

Given the heat and duration of the Lone Fire, we expected high direct mortality on low mobility species and lower abundance within the first year. However, in the first 4 years, lizards increased in abundance, and some species readily colonized burned forest. Our evidence suggests that there were enough fire survivors to colonize burned areas, and immigrants added little to the population. Lizard abundance was much greater in burned vegetation, as we captured 700 individuals in burned forest but only 161 in unburned forest; likewise in chaparral we caught 690 lizards in burned sites and 274 in unburned. The 6 species of whiptail lizards we captured were all more numerous in burned habitats than in unburned. Western whiptails, Sonoran whiptails, little striped whiptails, tree lizards, and even eastern fence lizards were captured from 4 to 20 times more frequently in burned vegetation than unburned.

However, even if short-term effects of a catastrophic fire seem beneficial for lizard communities, long-term effects of the loss of the ponderosa pine forest may be negative. The lower abundance and number of species on the smaller forested island on Mt. Ord may be a predictor of the future for the fire-reduced ponderosa pine forest on Four Peaks. In 4 years since the fire, we did not see any ponderosa pine reproduction, and the pine forest may not return (Swetnam and Baisan 1996). The long-term effect of the loss of ponderosa pine habitat will not be determined for many years, but decreased diversity and abundance is likely, particularly for pine forest adapted lizard species.

Low small mammal abundance in both burned and unburned vegetation was

unexpected. Low abundance may indicate other factors affected small mammal numbers previous to or simultaneously with the Lone Fire. Kangaroo rats responded very positively to the burn in chaparral, whereas the burn negatively affected white-throated woodrats. Seasonal small mammal differences may have been due to species having young during different months. Similar to lizards, there were more species present in higher numbers on Four Peaks than Mt. Ord.

We expected medium sized carnivores to avoid the blaze by moving ahead of the fire, but the 4 gray fox, 2 bobcats, and 1 coyote we were monitoring at the time of the blaze stayed in their territories, and assumedly escaped mortality by denning in rock piles or a burrow. Given previous studies, we expected gray fox, coyote, and bobcat numbers to increase because of more vulnerable prey, however, all 3 species declined within 6 months and scat densities were below pre-fire levels for at least 2 years. We believe this was primarily due to lack of plant food, and more vulnerable prey were not available. The majority of gray fox and coyote diet was soft mast, primarily manzanita, juniper, and prickly pear fruits, all of which were affected by the burn. The loss of soft mast and hunting cover affected carnivore densities negatively. After 2 years, however, gray fox, coyote, and bobcat density increased, and their diets were similar to unburned areas.

With black bears, our findings were also different from expectations. Black bears seemed to disappear from the burned area for the first few months, but the next summer were readily found and captured in green islands of vegetation missed by the fire. We had the benefit of having excellent pre-fire information on black bears in this area gathered by LeCount in the 1970s, and we were able to compare our information to his, and bears on a nearby sky island, Mt.

Ord. Given black bear ability to move quickly and long distances to find resources they need to survive, we expected the fire to only impact them temporarily (1-2 years).

There were major demographic differences within the black bear population that returned from what LeCount's earlier research found. Only a few resident females returned and tried to survive and rear cubs in small islands of vegetation with 4 times as many males as females living in the same areas. We captured 10 fewer adult females than LeCount captured, and do not know if previous residents were killed by the fire, or tried to find a new territory elsewhere. Black bear density within these islands was as high as prime habitat in Alaska or New England. We thought there would be high competition by black bears for food the first couple of years, and maybe even predation of smaller bears by larger bears. However, predation on adult black bears was not documented. Also, we did not document cub survivorship within the burn, nor immigration into the burn by other new females; so the reduced female population never returned to pre-fire levels. Thus, the Lone Fire had immediate and at least 4-year negative effects on black bears, and the return of the population will depend on habitat recovery.

Fortunately, vegetation islands missed by fire provided black bears with habitat similar to what they selected on Mt. Ord. Black bears selected areas with both high horizontal and vertical cover, and the number of shrubs >1.2 m tall was the most consistent predictor of black bear habitat use. Vertical cover (>75%) was also important for black bears and was primarily provided by large trees. Therefore, loss of the ponderosa pine forest probably reduced the amount of bedding and feeding habitat. Measures of cover in chaparral indicate it will take >5 years to reestablish shrub size and density that black bears select, but we

doubt it will take much longer than that. Deciduous trees (oaks) within chaparral are already returning, but not coniferous trees. We do not know if the loss of coniferous trees within chaparral will reduce the quality of that habitat as well.

In conclusion, the stand replacement fire on the Four Peaks sky island generally had negative effects on wildlife of different mobility. The immediate reaction of some small species was positive (e. g., whiptail lizards, tree lizards, kangaroo rats), but others were affected negatively (e. g., short horned lizards [*Phrynosoma douglasii*], white-throated woodrats). Mid-sized carnivores and black bears declined almost immediately after the fire. Mid-sized carnivores returned to pre-fire levels. Black bears were the most negatively affected species. Our data indicate the loss or reduction in size of the ponderosa pine forest may have long-term negative effects on many of these species.

Therefore, a "let-burn" policy on all fires may not be ecologically sound. Stand replacement "hot" fires after drought periods can have negative effects on wildlife, particularly in sensitive ecosystems like sky islands where loss or reduction of a habitat type is possible. Most of our data suggest high fire survivorship, but changes in vegetation were detrimental to some wildlife species.

We are not implying that a fire under less rigorous conditions (e. g. natural fire during years of normal precipitation or prescribed) would have negative impacts on wildlife. In fact, our data indicate smaller, cooler fires could have positive effects on wildlife, along with reducing the possibility of a catastrophic fire. More research needs to be conducted on the effects of different intensities of fires on wildlife.

## MANAGEMENT IMPLICATIONS

Based on fire frequency research, none of these species evolved in situations where fire killed so much vegetation and destroyed an ecosystem. However, land-use changes and fire suppression can greatly increase fire heat, size, and vegetation mortality. Because of the effects on wildlife we documented, we believe the primary management effort for a sky island should be to maintain species composition, diversity of vegetation stages, and forest size. To maintain sky islands and reduce fire intensity, the build up of fuels needs to be reduced. Returning fire frequency nearer to historical rates by controlled burning, or reduce fire risk through “thinning” is recommended.

Size and scheduling of burns and/or thinning should favor the greatest diversity of successional stages, both in forest and chaparral. This may require multiple fires or thinning areas within the same year, and multiple treatments will mimic historical fire history. A program to maintain at least 25% of black bear habitat in early successional stages was recommended in Arizona (Mollohan 1987, LeCount and Yarchin 1990), Idaho (Unsworth et al. 1989), Alaska (Schwartz and Franzmann 1991), and eastern Canada (Samson and Huot 1998). This goal would probably be positive for many wildlife species and reduce the chances of a catastrophic fire.

Some describe presettlement Arizona forests as a low density, large dbh ponderosa pine forest, with just perennial grass ground cover. This may not provide the amount of horizontal cover or food that some small mammals, mid-sized carnivores or black bears prefer. We found the presence of shrubs in close proximity to large trees for food and bedding is optimal for black bears, and the presettlement distribution of shrubs is largely unknown. During controlled

burns or thinning, portions of shrub cover on slopes >45% near natural topographic breaks (boulders, drainages), and in select areas next to large trees should be retained. Retaining snags and large down logs in all areas is also recommended.

If large-scale burns or thinning is used, retention of unburned islands and travel corridors are recommended. LeCount and Yarchin (1990) recommended maintaining travel corridors between different aged stands of vegetation of 100 m, particularly along drainageways. Although difficult, it would also help reestablish wildlife to preserve unburned areas when fighting a catastrophic wildfire.

The only attempt at reforestation after the Lone Fire was to mitigate damage to the watershed. Reestablishment of the ponderosa pine forest was not attempted, and no pine recruitment was documented during our study. Because of the importance of ponderosa pine and the forest island size we suggest reforestation begin. Ponderosa pine seedlings could be established from seeds produced by the remaining pines to ensure site-specific genetic integrity and disease resistance.

To help reestablish black bears within burned areas, we recommend transplanting females captured in “nuisance” bear situations to the burn perimeter. As humans continue to establish homes in black bear habitat in Arizona, negative human-bear interactions increase, and areas where nuisance bears can be released are limited. Since we found a significant decline in female residents with little to no recruitment, both wildfire and controlled burn areas should be considered for release of females.

Managers may need to consider different hunting strategies for black bears within a burned area for a limited time period. The skewed sex ratio effects on cub survival may be difficult to reverse without

removing males. An early spring black bear hunt of bears without cubs could increase the number of males harvested. This may help bring the sex ratio back to the normal 1:1 ratio documented in other black bear populations. A quota system to protect females would have to be established as well, as additional mortality of females could make it more difficult for the population to return to normal. The period of time needed for black bears to reestablish and to change hunting strategy is unknown and should be monitored. Given Arizona's current hunt structure and the large size of management units, change in the hunt structure of an entire unit (spring bear hunt, reduction in female quota) is unnecessary.

### **Research Needs**

We had hoped our microsite data would lend itself to the capabilities of remote sensing (GIS) for modeling potential black bear use, particularly post-fire shrub density, and allow management at the "landscape level". However, we were not able to measure plant density using GIS reflective bands. Since plant density and cover are important to black bears and other species, to currently measure shrub density "on the ground" would be cost-prohibitive. Further research with GIS and satellite imagery needs to be conducted to determine if areas of high shrub density, thick understory under forest canopy, return of shrub density to pre-burn levels, etc. can be determined using various remote sensing techniques.

### **ACKNOWLEDGEMENTS**

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APPENDICES

Appendix 1. Number of each lizard species captured in burned and unburned chaparral, and burned and unburned forest on Four Peaks and Mt. Ord in the Mazatzal Mountains, Arizona, 1996-99.

( ) = number of immatures.

Family Common Name <i>Species</i>	Burned Chaparral	Unburned Chaparral	Burned Forest	Unburned Forest	Total Captures
<b>Teiidae</b>					
Western whiptail <i>Cnemidophorus tigris</i>	357 (244)	52 (25)	7 (3)	0 (0)	416 (272)
Sonoran spotted whiptail <i>Cnemidophorus sonorae</i>	34 (15)	6 (4)	16 (6)	0 (0)	56 (25)
Gila spotted whiptail <i>Cnemidophoru flagellicaudus</i>	28 (9)	7 (1)	7 (1)	0 (0)	42 (11)
Plateau striped whiptail <i>Cnemidophorus velox</i>	27 (8)	17 (6)	34 (10)	2 (1)	80 (25)
Little striped whiptail <i>Cnemidophorus inornatus</i>	26 (15)	19 (8)	92 (53)	15 (10)	152 (86)
Desert grassland whiptail <i>Cnemidophorus uniparens</i>	3 (3)	3 (2)	3 (1)	1 (0)	10 (6)
<b>Phrynosomatidae</b>					
Eastern fence lizard <i>Sceloporus undulatus</i>	124 (85)	138 (90)	450 (304)	126 (66)	838 (545)
Desert spiny lizard <i>Sceloporus magister</i>	2 (1)	2 (1)	0 (0)	0 (0)	4 (2)
Clark's spiny lizard <i>Sceloporus clarkii</i>	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)
Tree lizard <i>Urosaurus ornatus</i>	55 (37)	4 (3)	43 (31)	2 (1)	104 (72)
Greater earless lizard <i>Cophosaurus texanus</i>	10 (8)	1 (0)	0 (0)	0 (0)	11 (8)
Lesser earless lizard <i>Holbrookia maculata</i>	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)
Short-horned lizard <i>Phrynosoma douglasii</i>	1 (1)	8 (2)	14 (10)	6 (4)	29 (17)
<b>Crotaphytidae</b>					
Eastern collared lizard <i>Crotaphytus collaris</i>	8 (8)	8 (3)	11 (11)	0 (0)	27 (22)
<b>Gekkonidae</b>					
Western banded gecko <i>Coleonyx variegatus</i>	22 (9)	1 (1)	7 (7)	0 (0)	30 (17)
<b>Scincidae</b>					
Great plains skink <i>Eumeces obsoletus</i>	3 (1)	6 (5)	4 (4)	0 (0)	13 (10)
<b>Helodermatidae</b>					
Gila monster <i>Heloderma suspectum</i>	0 (0)	1 (1)	0 (0)	0 (0)	1 (1)
<b>Anguidae</b>					
Madrean alligator lizard <i>Elgaria kingii</i>	0 (0)	1 (0)	14 (2)	7 (2)	22 (4)
<b>Total Captures</b>	700 (444)	274 (152)	702 (443)	161 (86)	1,837

Appendix 2. Number of each small mammal species captured in burned and unburned chaparral, burned and unburned forest on Four Peaks and Mt. Ord in the Mazatzal Mountains, Arizona, 1997-99.

Family Common name <i>Species</i>	Burned Chaparral	Unburned Chaparral	Burned Forest	Unburned Forest	Total
<b>Muridae</b>					
Deer mouse <i>Peromyscus maniculatus</i>	1	10	14	11	36
Brush mouse <i>Peromyscus boylii</i>	26	15	20	58	119
White-footed mouse <i>Peromyscus leucopus</i>	0	0	1	0	1
Cactus mouse <i>Peromyscus eremicus</i>	34	16	20	0	70
White-throated woodrat <i>Neotoma albigula</i>	1	10	0	6	17
Stephen's woodrat <i>Neotoma stephensi</i>	0	0	1	0	1
Northern grasshopper mouse <i>Onychomys leucogaster</i>	1	0	0	0	1
Southern grasshopper mouse <i>Onychomys torridus</i>	1	0	0	0	1
<b>Heteromyidae</b>					
Silky pocket mouse <i>Perognathus flavus</i>	5	0	0	0	5
Bailey's pocket mouse <i>Perognathus baileyi</i>	38	68	0	0	106
Rock pocket mouse <i>Perognathus intermedius</i>	8	0	0	0	8
Longtail pocket mouse <i>Perognathus formosus</i>	2	1	0	0	3
Ord's kangaroo rat <i>Dipodomys ordii</i>	58	3	0	0	61
Merriam's kangaroo rat <i>Dipodomys merriami</i>	38	2	0	0	40
<b>Geomyidae</b>					
Pocket gopher <i>Thomomys</i> spp.	2	0	2	0	4
<b>Scuridae</b>					
Chipmunk <i>Eutamias</i> spp.	0	0	2	3	5
Yuma antelope squirrel <i>Ammospermophilus harrisi</i>	1	0	0	0	1
<b>Soricidae</b>					
Desert shrew <i>Notiosorex crawfordi</i>	0	1	5	1	7
<b>Total Captures</b>	216	126	65	79	486

Appendix 3. Percent frequency of occurrence of diet as determined from gray fox scat collected in burned and unburned vegetation on Four Peaks and Mt. Ord in the Mazatzal Mountains, Arizona, 1996-99. – indicates that food item did not occur in that sample.

FOOD ITEM	1996		1997		1998		1999	
	Burned (n=17)	Unburned (n=105)	Burned (n=40)	Unburned (n=176)	Burned (n=71)	Unburned (n=186)	Burned (n=44)	Unburned (n=51)
<b>Hard Mast</b>	-	10.5	11.5	1.1	1.4	0.5	-	-
Oak <i>Quercus</i> spp.	-	-	2.5	1.1	1.4	-	-	-
Mesquite <i>Prosopis</i> spp.	-	10.5	17.5	-	-	0.5	-	-
<b>Soft Mast</b>	41.2	40.0	42.5	63.1	76.1	78.5	52.3	34.5
Manzanita <i>Arctostaphylos pungens</i>	-	10.5	10.0	12.5	40.9	24.7	22.7	23.5
Barberry <i>Berberis fremontii</i>	-	1.0	7.5	3.4	1.4	2.2	-	-
One-seed juniper <i>Juniperus monosperma</i>	-	10.5	12.5	4.6	10.0	41.4	22.7	19.6
Serviceberry <i>Amelanchier bakerii</i>	-	-	-	29.0	-	-	-	-
Wolfberry <i>Lycium pallidum</i>	-	-	7.5	2.8	-	-	-	-
Mimosa <i>Mimosa</i> spp.	-	-	-	-	-	0.5	-	-
Jojoba <i>Simmondsia chinensis</i>	-	-	-	2.3	4.2	1.1	-	-
Desert hackberry <i>Celtis pallida</i>	-	4.8	2.5	1.7	1.4	0.5	-	-
Buckthorn <i>Rhamnus</i> spp.	-	-	-	4.6	1.4	1.6	-	-
Canyon grape <i>Vitis arizonica</i>	-	-	2.5	1.7	1.4	2.2	-	-
Ground cherry <i>Physalis versicolor</i>	-	1.0	2.5	0.6	-	-	-	-
Squawbush <i>Condalia spathulata</i>	-	-	2.5	1.7	-	-	-	-
Prickly pear <i>Opuntia engelmannii</i>	41.2	16.2	2.5	5.7	4.2	11.8	20.5	5.9
Saguaro <i>Cereus giganteus</i>	-	-	-	-	11.3	3.2	-	-
Hedgehog cactus <i>Echinocereus</i> spp.	-	-	2.5	1.7	-	-	-	-
Blue yucca <i>Yucca baccata</i>	-	-	-	1.7	-	-	-	-
Unknown	-	1.0	-	2.3	4.2	4.3	2.3	2.0
<b>Grass</b>	5.9	1.0	12.5	7.4	14.1	8.1	11.4	11.8
<b>Graminae</b>								
<b>Large Mammals</b>	-	5.7	2.5	2.8	4.2	3.8	-	2.0
Deer	-	1.9	2.5	2.3	2.8	2.2	-	2.0
Cervidae								
Cattle	-	1.9	-	0.6	1.4	1.1	-	-
Bovidae								
Javelina <i>Tayassu tajacu</i>	-	1.9	-	-	-	0.5	-	-
<b>Small Mammals</b>	41.2	44.8	32.5	28.4	42.2	25.3	40.9	78.4
Ringtail <i>Bassariscus astutus</i>	-	1.9	-	0.6	-	-	-	-
Skunk <i>Mephitis</i> spp.	-	-	-	-	-	0.5	-	-

Appendix 3. (continued) Percent frequency of occurrence of diet as determined from gray fox scat collected in burned and unburned vegetation on Four Peaks and Mt. Ord in the Mazatzal Mountains, Arizona, 1996-99. – indicates that food item did not occur in that sample.

FOOD ITEM	1996		1997		1998		1999	
	Burned (n=17)	Unburned (n=105)	Burned (n=40)	Unburned (n=176)	Burned (n=71)	Unburned (n=186)	Burned (n=44)	Unburned (n= 51)
Gray fox <i>Urocyon cinereoargenteus</i>	-	1.0	-	0.6	-	-	-	-
Coyote <i>Canis latrans</i>	-	1.0	-	-	-	-	-	-
Domestic dog	-	-	-	0.6	-	-	-	-
Rabbit	23.5	18.1	15.0	9.1	8.5	6.5	13.6	17.6
Leporidae								
Rodent	23.5	26.7	17.5	17.1	33.8	20.0	27.3	62.8
Rodentia								
<b>Other Animals</b>	23.5	24.8	37.5	26.1	28.2	16.7	13.6	13.7
Birds	5.9	7.6	17.5	4.6	10.0	4.3	4.6	5.9
Aves								
Insect	11.8	20.0	20.0	18.2	25.4	13.4	11.4	7.8
Arthropoda								
Reptile	5.9	-	2.5	3.4	1.4	-	-	-
Reptilia								

Note: Plant common and scientific names are consistent with Kearney and Peebles 1960.

Appendix 4. Percent frequency of occurrence of diet as determined from coyote scat collected in burned and unburned vegetation on Four Peaks and Mt. Ord in the Mazatzal Mountains, Arizona, 1996-99. – indicates that food item did not occur in that sample.

FOOD ITEM	1996		1997		1998		1999	
	Burned (n=15)	Unburned (n=25)	Burned (n=5)	Unburned (n=14)	Burned (n=33)	Unburned (n=21)	Burned (n=22)	Unburned (n=32)
<b>Hard Mast</b>	13.3	44.0	20.0	-	-	-	-	-
Oak	-	4.0	-	-	-	-	-	-
<i>Quercus</i> spp.								
Mesquite	13.3	40.0	20.0	-	-	-	-	-
<i>Prosopis</i> spp.								
<b>Soft Mast</b>	20.0	16.0	-	35.7	69.7	61.9	18.2	43.7
Manzanita	-	4.0	-	28.6	45.5	28.6	13.6	31.3
<i>Arctostaphylos pungens</i>								
Barberry	13.3	-	-	-	-	-	-	-
<i>Berberis fremontii</i>								
One-seed juniper	-	4.0	-	-	18.2	9.5	9.1	12.5
<i>Juniperus monosperma</i>								
Wolf berry	-	-	-	-	3.0	-	-	-
<i>Lycium pallidum</i>								
Mimosa	-	-	-	-	-	4.8	-	-
<i>Mimosa</i> spp.								
Jojoba	-	-	-	7.1	3.0	-	-	-
<i>Simmondsia chinensis</i>								
Desert hackberry	-	-	-	-	-	4.8	-	-
<i>Celtis pallida</i>								
Prickly pear	6.7	4.0	-	-	-	9.5	-	3.1
<i>Opuntia engelmannii</i>								
Saguaro	-	-	-	-	-	9.5	-	-
<i>Carnegiea gigantea</i>								
Unknown	-	-	-	-	-	-	-	3.1
<b>Grass</b>	13.3	-	-	14.3	15.2	9.5	-	9.4
Graminae								
<b>Large Mammals</b>	6.7	20.0	-	28.6	3.0	9.5	-	-
Deer	-	4.0	-	7.1	3.0	4.8	-	-
Cervidae								
Cattle	-	12.0	-	21.4	-	4.8	-	-
Bovidae								
Javelina	6.7	-	-	-	-	-	-	-
<i>Tayassu tajacu</i>								
<b>Small Mammals</b>	40.0	64.0	100.0	35.7	39.4	57.1	90.9	71.9
Raccoon	-	-	-	-	-	4.8	-	-
<i>Procyon lotor</i>								
Ringtail	-	4.0	20.0	7.1	-	-	-	-
<i>Bassariscus astutus</i>								
Rabbit	-	36.0	-	28.6	9.1	42.9	-	-
Leporidae								
Rodent	46.7	12.0	40.0	21.4	30.0	14.3	77.3	75.1
Rodentia								
Domestic cat	6.7	-	-	-	3.0	-	-	-
Felidae								
<b>Other Animals</b>	20.0	12.0	-	21.4	30.3	-	4.6	6.3
Insect	20.0	8.0	-	7.1	12.1	-	-	-
Arthropoda								
Bird	6.7	4.0	-	14.3	12.1	-	4.6	6.3
Aves								
Reptile	-	-	-	7.1	3.0	-	-	-
Reptilia								

Note: Plant common and scientific names are consistent with Kearney and Peebles 1960.

Appendix 5. Percent frequency of occurrence of diet as determined from black bear scats collected in burned and unburned habitats on Four Peaks and Mt. Ord in the Mazatzal Mountains, Arizona, 1997-99. – indicates that food item did not occur in that sample.

FOOD ITEM	Frequency of Occurrence	
	Burned 1997-99 (n = 91)	Unburned 1997-99 (n = 154)
<b>Plant Material</b>	97.8	98.0
Grass	53.8	42.9
Graminae		
<b>Soft Mast</b>	45.0	61.0
Manzanita	35.2	22.7
<i>Arctostaphylos</i> spp.		
Serviceberry	5.5	13.6
<i>Amelanchier bakerii</i>		
Barberry	1.1	0.6
<i>Berberis fremontii</i>		
One-seed juniper	4.4	18.2
<i>Juniperus monosperma</i>		
Choke cherry	2.2	1.9
<i>Prunus virginiana</i>		
Arizona grape	-	1.3
<i>Vitis arizonica</i>		
Hackberry	-	0.6
<i>Celtis pallida</i>		
Prickly pear	2.2	7.8
<i>Opuntia engelmanni</i>		
<b>Hard Mast</b>		
Oak acorns	35.2	14.3
<i>Quercus</i> spp.		
<b>Animal Matter</b>	30.5	18.8
<b>Large Mammals</b>		
Deer	5.5	-
Cervidae		
Cattle	-	1.9
Bovidae		
Carnivore	1.1	-
Carnivora		
<b>Small Mammals</b>		
Rodent	2.3	2.6
Rodentia		
Rabbit	1.1	-
Leporidae		
<b>Other</b>		
Insect	19.8	11.0
Arthropoda		
Ant	4.4	3.9
Formicidae		
Birds	-	1.3
Aves		

Appendix 6. Percent frequency of occurrence of diet by year as determined from black bear scat collected in both burned and unburned sites on Four Peaks and Mt. Ord in the Mazatzal Mountains, Arizona, 1997-99. – indicates that food item did not occur in that sample.

FOOD ITEM	1997		1998		1999	
	Burned (n = 54)	Unburned (n = 52)	Burned (n = 28)	Unburned (n = 67)	Burned (n = 9)	Unburned (n = 35)
<b>Plant Material</b>	100.0	96.1	96.4	98.5	88.9	100.0
Grass	50.0	30.8	57.1	59.7	66.7	28.6
Graminae						
<b>Soft Mast</b>	40.7	75.0	50.0	43.3	55.6	74.3
Manzanita	27.8	25.0	42.9	22.4	55.6	20.0
<i>Arctostaphylos</i> spp.						
Serviceberry	9.3	38.5	-	1.5	-	-
<i>Amelanchier bakerii</i>						
Barberry	1.8	1.9	-	-	-	-
<i>Berberis fremontii</i>						
One-seed juniper	1.8	1.9	3.6	10.4	22.2	57.1
<i>Juniperus monosperma</i>						
Choke cherry	3.7	5.8	-	-	-	-
<i>Prunus virginiana</i>						
Arizona grape	-	1.9	-	1.5	-	-
<i>Vitis arizonica</i>						
Hackberry	-	1.9	-	-	-	-
<i>Celtis pallida</i>						
Prickly pear	1.8	7.7	3.6	11.9	-	-
<i>Opuntia engelmanni</i>						
<b>Hard Mast</b>						
Oak acorns	35.2	19.2	46.4	14.9	-	5.7
<i>Quercus</i> spp.						
<b>Animal Matter</b>	29.6	34.6	33.3	11.9	44.4	11.4
<b>Large Mammals</b>						
Deer	1.8	-	14.3	-	-	-
Cervidae						
Cattle	-	3.8	-	1.5	-	-
Bovidae						
Carnivore	-	-	3.6	-	-	-
Carnivora						
<b>Small Mammals</b>						
Rodent	1.8	1.9	-	1.5	11.1	5.7
Rodentia						
Rabbits	1.8	-	-	-	-	-
Leporidae						
<b>Other</b>						
Insects	20.4	17.3	14.3	9.0	33.3	5.7
Arthropoda						
Ants	7.4	11.5	-	-	-	-
Formicidae						
Birds	-	3.8	-	-	-	-
Aves						





