MOUNTAIN LION DEPREDATION HARVESTS IN ARIZONA, 1976 TO 2005

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ABSTRACT

We studied reported kills of mountain lions (*Puma concolor*) in Arizona related to livestock depredation events between 1976 and 2005 to determine if a relationship existed between mule deer (*Odocoileus hemionus*) abundance and livestock depredation. Depredation-related kills of mountain lions increased and contributed substantially to statewide hunter harvest of mountain lions when mule deer abundance waned. Depredation-related kills of mountain lions were negatively correlated with mule deer abundance. Depredation-related kills of mountain lions involved primarily adult males, but take of all age and sex classes of mountain lions increased concurrently. Cattle depredation initiated 90% of all reported mountain lion kills for depredation, and 98% of these reports involved depredation on calves. Mountain lions killed for depredation of cattle occurred in 12 of the state's 15 counties, although 5 counties accounted for 92% of all depredation kills. We believe that reduced relative abundance of mule deer contributes to increased depredation of cattle by mountain lions in Arizona.

INTRODUCTION

Predator reduction to mitigate domestic livestock depredation or benefit wildlife populations is a controversial action for wildlife management agencies (Ballard et al. 2001). Substantial and widespread conflicts between humans and large carnivores arise due to depredations of livestock, resulting in predator removals (Linnell et al. 1999). The public has widely disparate views on lethal removal of predators that threaten livestock or other domestic prey (Casey et al. 2005). Predator control efforts in Arizona between 1947 and 1969, when the state legislature offered a bounty on mountain lions (*Puma concolor*), resulted in 5,400 payments (Phelps 1989). In 1970, mountain lions were classified as big game by the Arizona legislature, and regulated take of mountain lions for reported depredations of livestock began in 1971 (Arizona Game and Fish Department 2006). Many western state wildlife management agencies consider depredation of livestock and other domestic animals by mountain lions an important management concern (Ballard et al. 2001, Torres et al. 1996, Barber 2005, Winslow 2005, Woolstenhulme 2005).

Depredations of cattle by mountain lions occurs in 11 western states, but is highest in Arizona (Shaw 1983, Cunningham et al. 1995, Cunningham et al. 2001, Mountain Lion Foundation 2007, www.pumaconservation.org/html/printable_version.html). About 850 livestock operators presently graze about 56,000 cattle on public lands in Arizona (Bureau of Land Management 2006, blm.gov/az/range.htm). Calves comprised an estimated 93% of cattle killed by mountain lions on a ranch in north-central Arizona (Shaw 1983). Calves comprised 44% of biomass eaten by mountain lions in southeastern Arizona (Cunningham et al.

1999). Other studies in Arizona reported cattle comprised 13% (Cashman et al. 1992), 14% (McKinney et al. 2006), and 26% (Shaw 1977) of mountain lion diets.

Hunter harvest is considered the primary cause of mountain lion mortality in hunted populations (Ruth et al. 1998, Logan and Sweanor 2001), but killing mountain lions that prey on livestock might account for a substantial portion of human-related mortality of the predator in Arizona (Cunningham et al. 1995, 1999). Depredation harvest has been the primary cause of mountain lion mortality in southeastern Arizona (Cunningham et al. 2001), and it accounted for 15% of all mountain lions harvested in Arizona between 1996 and 2004 (Barber 2005).

Depredation incidents involving mountain lions increased in California between 1972 and 1995 (Torres et al. 1996), and depredation harvest of mountain lions in Montana increased between 1971 and 1990 (Aune 1991). Depredation by mountain lions is affected by a complex interaction of factors (e.g., Shaw 1981), but not all have been adequately quantified. Our objectives were to describe statewide patterns, trends, and demographics of confirmed legal depredation harvest of mountain lions, quantify depredation of cattle and other prey by mountain lions, and determine relationships between kills of mountain lions for depredation, hunter harvest of mountain lion, and abundance of mule deer (*Odocoileus hemionus*).

METHODS

Nuisance and public safety issues associated with mountain lions are addressed differently than depredation by mountain lions (killing livestock or other domestic animals) in Arizona. Livestock operators are allowed to kill depredating mountain lions and must follow strict reporting requirements (Barber 2005). Records of mountain lion depredation kills and data on depredation of livestock have been maintained in Arizona since 1971, although data record consistency was incomplete through 1975 (Arizona Game and Fish Department 2006). The authors analyzed mountain lion depredation-related kill data between 1976 and 2005 only when depredation permits were issued, age and sex of depredating mountain lions were estimated, and depredated species and locations of depredation were were provided. We used data from depredation-related mountain lion kills where age and sex of mountain lions were provided by persons involved with mountain lion removal, based on necropsies, pelage, or tooth wear.

We also analyzed statewide data for hunter harvests of mountain lions and mule deer between 1976 and 2005 (Arizona Game and Fish Department 2006), and indexed mule deer abundance using harvest data (Marshal et al. 2002). We used Spearman's rank correlations to determine trends of mountain lion depredation and sport harvests, prey that were depredated, and abundance of mule deer. We used simple linear regression models to determine correlation between confirmed depredation harvest of mountain lions as the dependent variable and indexed abundance of mule deer as an independent variable. We then compared proportions of mountain lion adults, subadults, sexes, and mean sex ratio of adults and subadults in depredation harvests using Yate's adjusted chi-square and 2 x 2 contingency tables and *t*-tests, respectively (Zar 1996).

RESULTS

We documented 917 confirmed depredation incidents by mountain lions between 1976 and 2005 (Figure 1), with a mean of 30.6 depredation-related mountain lion kills per year (SD = 18.96, range = 2 to 66/year). Depredation-related kills of mountain lions during this period averaged 14.8% (SD = 10.33, range = 1.0 to 50.0%) of statewide hunter harvest of mountain lions. Hunter harvest of mountain lions was highly variable among years (R = 0.1638, t_{28} = 0,8786 P

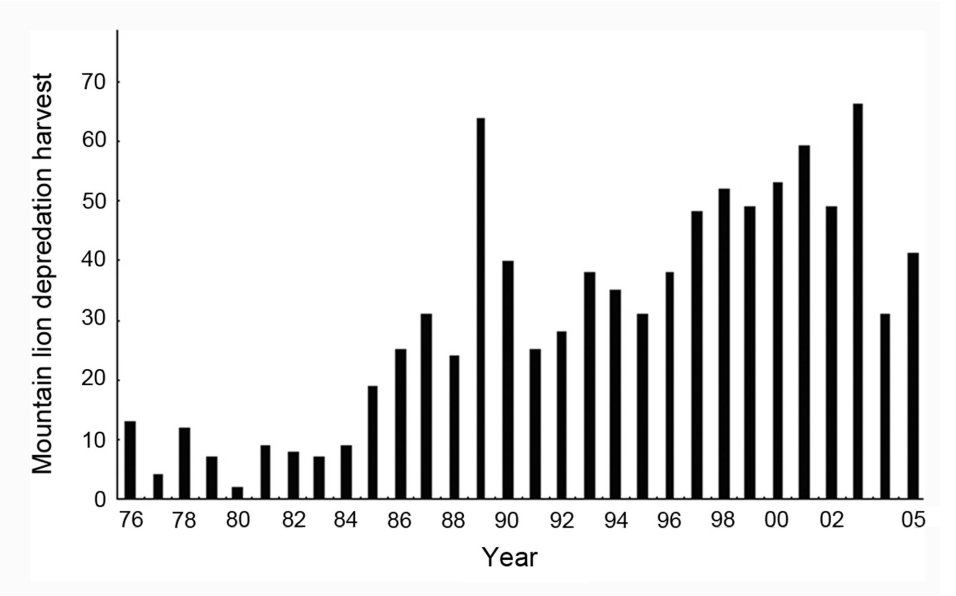

Figure 1. Confirmed number of mountain lions harvested for depredations in Arizona, 1976 to 2005.

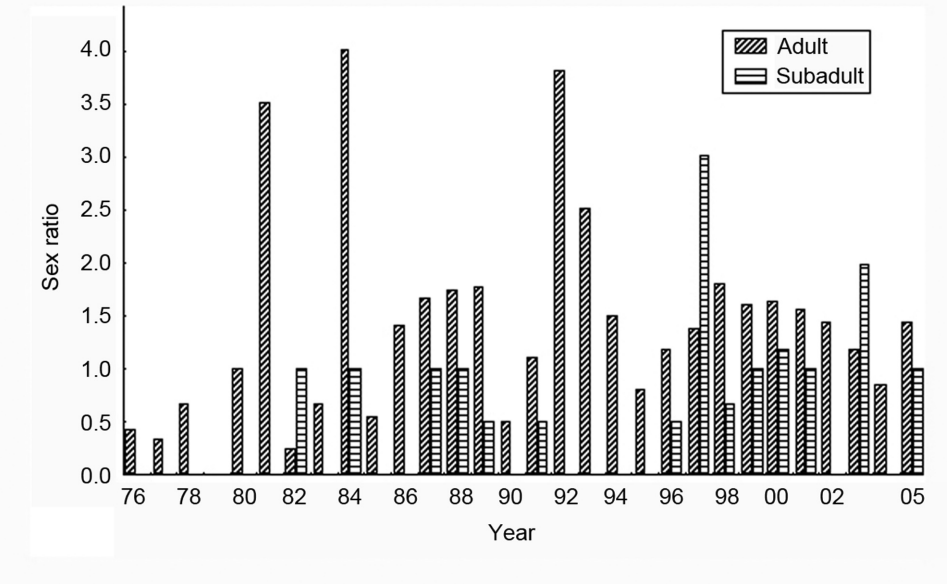

Figure 2. Sex ratios (M:F) of adult and subadult mountain lions harvested in confirmed depredation incidents in Arizona, 1976 to 2005.

= 0.387, SD = 43.83), but depredation-related kills as percent of hunter harvest of mountain lion increased after 1976 and was less variable than hunter harvest ($R = 0.7562$, $t_{28} = 6.115$, $P < 0.001$, SD = 10.33).

Of all depredation-related mountain lion kills between 1976 and 2005, 92.3% (847/917) occurred between 1985 and 2005; these kills comprised 17.9% (847/4,743) of hunter harvests. Between 1976 and 2005, depredation-related kills of all mountain lions—adult mountain lions (sexes combined), adult females, adult males, all females, and all males—increased ($R \geq 0.8108$, $t_{28} \geq 7.347$, $P < 0.001$). Similarly, depredation-related kills of subadult (sexes combined; $R = 0.6989$, $t_{28} = 5.171$, $P < 0.001$), subadult female ($R = 0.4480$, $t_{28} = 2.562$, $P = 0.013$), and subadult male mountain lions ($R = 0.5181$, $t_{28} = 3.206$, $P = 0.003$) increased between 1985 and 2005.

Females and males (combined age classes) were identified in 43.2% (356/825) and 56.8% (469/825) of depredation-related kills, respectively ($\chi^2 = 30.41$, $P < 0.001$). Adult and subadult mountain lions (combined sexes) were identified in 87.3% (729/835) and 12.7% (106/835) of depredation-related kills, respectively ($\chi^2 = 926.67$, $P < 0.001$). Among mountain lions classified as adults, females and males were identified in 42.1% (309/734) and 57.9% (425/734) of depredation-related kills, respectively ($\chi^2 = 36.64$, $P < 0.001$). Among mountain lions classified as subadults, females and males each were identified in 50% (47/94) of depredation-related kills. Mean sex ratio (M:F) of depredation-related kills (Figure 2) was 1.36 (SD = 0.89, range = 0.33 to 4.00). Mean sex ratios for adult and subadult mountain lions from depredation-related kills between 1976 and 2005 were 1.46 (SD = 0.96; range = 0.25 to 4.00) and 1.10 (SD = 0.67; range = 0.50 to 3.00), respectively, and did not differ ($t_{41} = 1.270$, $P > 0.211$). Sex ratios of adults ($R = 0.1967$, $t_{27} = 1.614$, $P > 0.118$) and subadults ($R = 0.3090$, $t_{12} = 1.126$, $P > 0.282$) from depredation-related kills showed no clear trends between 1976 and 2005.

Total reported depredation-related kills of mountain lions and depredations of cattle occurred most often between January and June, but reported depredations of other prey showed no clear seasonal pattern (Figures 3 and 4). Calves comprised 97.9% (573/585) of cattle depredations by mountain lions among events that specified relative ages of cattle killed. Other prey killed by mountain lions included chickens, colts, domestic goats and sheep, deer (*Odocoileus* spp.), domestic dogs, and ostriches (*Struthio camelus*). Depredation-related kills of mountain lions as a result of cattle depredation comprised 90.1% (826/917) of all reported depredation kills between 1976 and 2005 in Arizona. Mean harvest of mountain lions for depredation of cattle during this period was 26.7/year (SD = 20.71; range = 1 to 66/year), and mean harvest for depredation other than for cattle was 1.0/year (SD = 1.08; range = 0 to 3/year). Depredation of cattle ($R = 0.8328$, $t_{23} = 7.215$, $P < 0.001$) and calves ($R = 0.6958$, $t_{17} = 4.332$, $P < 0.001$) increased between 1976 and 2005, but depredation of other prey showed no annual trend ($R = 0.0693$, $t_{23} = 0.3330$, $P > 0.742$).

Statewide abundance of mule deer declined between 1976 and 2005 ($R = -0.6289$, $t_{28} = -4.280$, $P < 0.001$). Total depredation-related kills of all mountain lions (Figure 3; $F_{1, 28} = 8.18$, $r^2 = 0.2261$, $P < 0.008$, $b = -0.48$), all adults ($F_{1, 28} = 8.18$, $r^2 = 0.2261$, $P < 0.008$, $b = -0.48$), adult females ($F_{1, 28} = 18.19$, $r^2 = 0.3938$, $P < 0.001$, $b = -0.63$), adult males ($F_{1, 28} = 11.93$, $r^2 = 0.2788$, $P < 0.002$, $b = -0.55$), and subadults ($F_{1, 28} = 9.44$, $r^2 = 0.2521$, $P < 0.005$, $b = -0.50$) were negatively correlated with indexed abundance of mule deer.

Mountain lions harvested for cattle depredations were reported in 12 of Arizona's 15 counties. Depredation harvests in 5 contiguous counties each comprised >

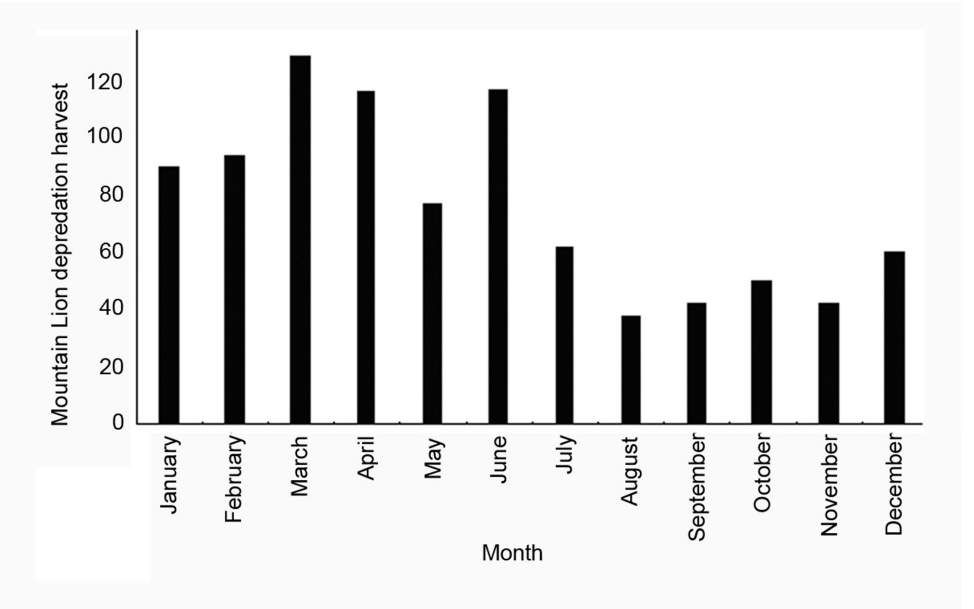

Figure 3. Monthly confirmed number of mountain lions harvested for depredations in Arizona, 1976 to 2005

6% of statewide cattle depredation harvests (Mohave [6.3%], Gila [7.7%], Graham [47.6%], Greenlee [24.2%], and Yavapai [6.5%]). These counties extend from northwestern to southeastern Arizona, and accounted for 92.4% (763/826) of reported depredation-related mountain lion kills for cattle depredations. The five counties encompass an estimated area of about 85,160 km^2 , or about 28.9% of the area of Arizona. Depredation harvests in the five counties between 2000 and 2005 comprised 19.0% (292/1,533) of statewide sport harvest of mountain lions (Arizona Game and Fish Department, 2006). Remaining counties each comprised < 3% of mountain lions killed for cattle depredations (Apache [0.7%], Coconino [0.5%], Maricopa [2.4%], Cochise [2.5%], Pima [0.5%], Pinal [0.2%], Santa Cruz [0.7%]). Mountain lion harvests for depredations of domestic prey other than cattle (e.g., goats, horses) occurred in 10 counties (Cochise, Coconino, Gila, Graham, Greenlee, Maricopa, Mojave, Navajo, Santa Cruz, and Yavapai).

DISCUSSION

Depredation incidents by mountain lions have increased throughout much of western United States during the past few decades. Most depredations outside of Arizona involve domestic sheep, but mountain lions also have killed cattle, horses, alpacas (*Vicugna pacos*), llamas (*Lama glama*), emus (*Dromaius novaehollandiae*), and human pets and smaller animals such as chickens, geese, and domestic pigs (Cougar Management Guidelines Working Group 2005). Our results paralleled trends observed between 1972 and 1995 of mountain lion depredaton incidents in California, where hunting of mountain lions is prohibited (Torres et al. 1996). Mountain lion kills for depredation-related incidents also increased after 1970 in Montana, where hunting mountain lions is legal (Aune 1991). Consistent with previous studies in two limited areas of Arizona (Shaw 1977; Cunningham et al. 1995, 1999), we found that most mountain lion depredation-related kills were associated with predation of cattle, and 98% of depredation-related kills involved depredation of calves.

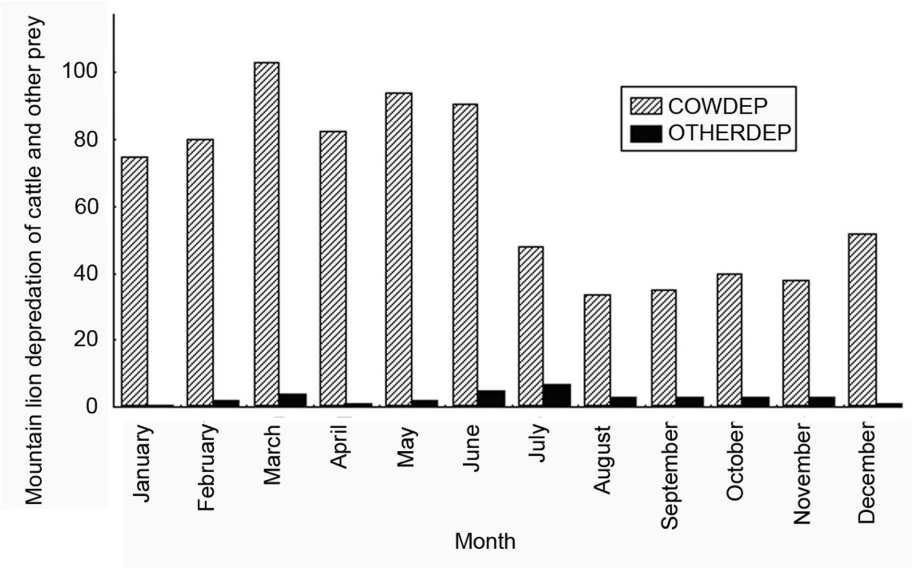

Figure 4. Monthly confirmed number of mountain lions harvested in response to depredations of cattle (COWDEP) and other prey (OTHERDEP) in Arizona, 1976 to 2005.

Depredation-related kills do not reliably index changes or trends in abundance of mountain lions (Cougar Management Guidelines Working Group 2005). Depredation-related kills contributed substantially to overall take of mountain lions in Arizona between 1976 and 2005, comprised on average 15% of hunter harvest, and ranged among years from <1–50% of hunter harvest.

About 92% of depredation-related kills from 1976 to 2005 occurred between 1985 and 2005, when they comprised 18% of sport harvest of mountain lions. The disproportionately high number of reports during 1985–2005 may have occurred at least in part because reporting requirements were better known and enforced than during 1976–1984. Adult males were killed for depredations more than adult females or subadults of either sex, consistent with previous findings (Aune 1991, Torres et al. 1996, Linnell et al. 1999, Cunningham et al. 2001, Woolstenhulme 2005). Mean sex ratio (M:F) of depredating mountain lions killed in our study (1.36) was higher than the average (1.14) for mountain lions harvested by hunters in Arizona between 1982 and 2002 (Zornes et al. 2006). Sex ratio also reportedly favored males (M:F = 1.48) for depredating mountain lions in California (Torres et al. 1996). The tendency for males to predominate in depredation-related kills has not been adequately explained, but males are not likely to be more vulnerable to methods of depredation take (Linnell et al. 1999).

Most mountain lion kills for depredation of cattle in Arizona occurred between January and June (Figure 4). In comparison, the number of calves and yearlings killed by mountain lions was highest between November and June in north-central Arizona (Shaw 1977). Estimated relative number of calves killed by mountain lions also increased during autumn and winter in southeastern Arizona (Cunningham et al. 1995). The higher predation of cattle by mountain lions in Arizona corresponds with the period of seasonal production of calves in free-ranging

herds (Shaw 1977). In addition, a statewide survey in Arizona in 1984 indicated that the number of mountain lions killed for cattle depredations underrepresents the number of cattle killed by mountain lions (Shaw 1984).

Mountain lions occupy various habitat types throughout most of Arizona, and are believed to inhabit about 187,000 km^2 of suitable habitat that includes about 31,000 km^2 classified as high quality habitat (Barber 2005). Ninety-two percent of depredation harvests for predation of cattle occurred within five counties that comprise about 35% of habitat occupied by mountain lions. These counties are essentially contiguous with the northwest-southeast distribution of the chaparral zone in Arizona (Swank 1958). Vegetation consisting of Great Basin conifer and Madrean evergreen woodlands, Rocky Mountain and Madrean montane conifer forests, and Arizona Upland Sonoran Desert scrub also is contiguous with chaparral in much of the region (Brown 1994). Most reports of depredations of cattle by mountain lions in Arizona originate from mid-elevation chaparral and pine-oak (*Pinus* spp.-*Quercus* spp.) woodlands, with few documented in high-elevation or low desert areas. Vegetation types and topography within these five counties probably increase the likelihood that livestock will suffer from mountain lion predation. Further, the elevations are relatively low, temperatures are moderate, and habitat in these counties are conducive to yearlong stocking of cow-calf livestock operations, whereas higher elevation ranges may not allow for yearlong livestock operations that include age classes of cattle especially vulnerable to mountain lion predation.

Relationships between husbandry practices and mountain lion depredations of livestock have not been adequately demonstrated (Cougar Management Guidelines Working Group 2005). Nonetheless, depredation of cattle by mountain lions is often higher if free ranging cow-calf herds are grazed in areas of rugged terrain and dense vegetation cover, and if abundance of prey other than cattle is comparatively low (Shaw 1983; Cunningham et al. 1999; Bueno-Cabrera et al. 2005).

Yearlong cow-calf operations predominate in mountainous areas of Graham and Greenlee counties with the highest depredation rates, coincident with historically intensive mountain lion depredation control efforts that have contributed to low survival rates of mountain lions in some regions of Graham county (Dodd and Brady 1986, Cunningham et al. 2001). Between 1988 and 1993, hunters and depredation-control efforts removed 32 and 26 mountain lions, respectively, from one area of Graham county (Cunningham et al. 2001). Another 46 and 52 mountain lions were removed from the area between 2000 and 2005 by hunters and depredation control, respectively (Arizona Game and Fish Department 2005, 2006). Despite high mountain lion removal in these areas, large numbers of livestock suffer from mountain lion depredation annually.

Depredations of livestock concern ranchers and wildlife managers, but killing depredating mountain lions may provide only a short-term solution for preventing or reducing losses of cattle (Cougar Management Guidelines Working Group 2005, Graham et al. 2005). Intensive levels of hunter harvest of mountain lions may alter demographics and reduce populations of the predator, but mountain lion populations recover relatively rapidly if hunting pressure is not maintained over time (Lindzey et al. 1992, Ross and Jalkotzy 1992, Cunningham et al. 2001, Anderson and Lindzey 2005, Stoner et al. 2006). Longer-term solutions to depredation may require significant reductions in mountain lions over broad areas, reduction in the number of adult female mountain lions in an area, or modification of present husbandry practices, such as grazing cattle in low quality mountain lion habitat when calves are present (Shaw 1977, 1988,

Cougar Management Guidelines Working Group 2005). Research is needed to evaluate the effectiveness of different animal husbandry practices and hunt structures in reducing livestock depredations.

Potential explanations for increased depredations by mountain lions in western United States are speculative, but include factors such as changes in land use, elimination of bounties for mountain lions, increasing abundance of mountain lions, and declining abundance of deer (Cougar Management Guidelines Working Group 2005). Mule deer are the primary prey of mountain lions in North America, and are widely distributed in Arizona (Hoffmeister 1986; Lindzey et al. 1994). Abundance of mule deer may influence the abundance of mountain lions (Hemker et al. 1984; Lindzey et al. 1994, Pierce et al. 2000, Riley and Malecki 2001), but relationships between predator abundance and depredation are complex. Availability of natural prey influences depredation of cattle by mountain lions (Polisar et al. 2003), and our findings suggest that decline in abundance of mule deer corresponded with increased depredation-related kills of mountain lions in Arizona.

MANAGEMENT IMPLICATIONS

Fundamentally, reducing livestock depredation primarily requires avoiding the placement of livestock within good mountain lion habitat. Changing the type and age of livestock (e.g., switching to adult cattle, avoiding calves) grazed within an area with demonstrated depredation history may reduce the likelihood and frequency of depredation events. Improving habitat and encouraging healthy wildlife communities, including deer, on ranges grazed by livestock may provide predators with a natural prey base, thereby reducing depredation on cattle. Changes to the mountain lion populations, such as reductions in overall abundance or abundance of female mountain lions through hunter harvest or targeted removal may reduce depredation events, although little effect has been shown to occur through standard management practices. Research to determine the effectiveness of these various management alternatives should include a financial costs assessment.

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