est. 1990

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ABSTRACT

A free-ranging population of feral horses (Equus caballus) inhabiting a 600-km^2 area on the central California-Nevada border was studied between May 1986 and October 1990. The population comprised approximately 200 individuals with an average of 73.6% adults, 5.0% two year olds, 4.8% yearlings, and 17.1% foals. The annual rate of population change was <5.5% during the study period and showed no consistent trend. The peak of parturition occurred in May, when 55% of the annual observed foaling occurred. Average foal survival through June, based on missing foals, was 57%. The average annual foal survival rate, estimated from foal and yearling counts was 33%. A minimum of four adult mountain lions (Felis concolor) used the study area each year between May and October. Lion densities based on road track counts were approximately two times greater in January than in June. Of 28 foal carcasses located from May to mid-July during the study period, 82% were documented having been killed by mountain lions. No evidence of predation on horses other than foals was found.

Key Words: mountain lion, feral horse, predation, population data

INTRODUCTION

Large felids are recognized as predators of some wild equids. Predation of onagers (Equus hemionus) by lions (Panthera leo) and leopards (Panthera pardus) has been documented in central Asia (Solomatin 1973). In Africa, lions and spotted hyenas (Crocutta crocutta) are common predators of zebras (Equus burchelli) (Schaller 1972; Kruuk 1972) and these predators may regulate some zebra populations (Sinclair and Norton-Griffiths 1982).

The mountain lion is an effective predator of several ungulates, with mule deer (Odocoileus hemionus) and elk (Cervus elaphus) being the most common large prey in North America (Robinette et al. 1959; Hornocker 1970). Mountain lion predation on feral horses has been reported previously (Robinette et al. 1959; Ashman et al. 1983), but the phenomenon is usually considered to be an incidental or uncommon occurrence (Berger 1986). One apparent exception is the Montgomery Pass Wild Horse Territory (MPWHT) on the central California/Nevada border. Here, a moratorium on mountain lion (sport) hunting has been in effect since 1972 in California, which combined with limited hunting pressure in the Nevada portion of the area may have led to a high density of mountain lions (Kutilek 1981; Fitzhugh and Gorenzel 1986).

Aerial surveys and ground counts conducted during the past 12 years on the MPWHT have suggested that the feral horse population is numerically stable or declining slowly (USDA Forest Service Tech. Reports 1979; 1988). By contrast, studies of horse populations in

MATERIALS AND METHODS

Study Period

Data were collected on the MPWHT mountain lion population and feral horse population between May, 1986 and October 1990, emphasizing the months of May and June, two weeks in September and 1-2 weeks in January. Single day visits were made during other months. May through June was chosen as the focus for data collection on predation because this was the peak opportunity for finding freshly killed foals, i.e., maximal chance of differentiating actual predation from possible scavenging was greatest at this time. Also the bands of horses were centralized in the summer grazing area (an approximately 60 km^2 area) during this period.

Study Area

Situated on the central segment of the California-Nevada border, the MPWHT encompasses a remote area of approximately 600 km^2 centered at 38°00′ latitude and 118°30′ longitude. Elevations range from 1600-2600 m. During the study period the area received an average precipitation of 25 cm at 1500 m elevation, with increasing amounts (mostly as snowfall) at higher elevations. Free water was available from 5 permanent springs scattered through the study area.

Horse Population

The feral horse population of the MPWHT is a herd of approximately 200 animals with a harem band social structure (Turner et al. 1981; Turner and Kirkpatrick 1986). Individual horses were identifiable by coloration, face and leg markings, and band association (Berger 1986; Turner et al. 1981). This permitted monitoring of individual mares and their respective foals.

Identification data were collected for each band of horses and its individual members by means of photographic or videotape records, and band composition and individual horse descriptions were recorded, including number of animals, age (foal, immature, adult), sex, coat color, identifying marks (stockings, blaze, paint, etc.). The map location of a given band was also recorded for each observation occurrence.

The summer range area consisted of a central high point with a 360° view of hills and valleys radiating out and downward for 5-7 km and up to 70% of the population utilized this area from May to October. The interval between observations of bands in this area was rarely more than 2 days. The remainder of the herd was observed at intervals ranging from 3-7 days. Thus, during the peak foaling period (May - June) the presence of new foals was usually documented within 7 days, as was the loss of foals from a given band. Although it is possible that some foals were taken by lions during their first week, this was never observed in foals (n = 19) for which the birthdate (± 1 day) was known. Annual foal survival rates were estimated from the differential incidence of yearlings in one year and foals counted from the previous year (May to October). Foal carcass counts made from May to October in a given year included all foals known to be present during or prior to that period.

Both aerial and ground-based surveys were used to estimate horse numbers. Systematic aerial surveys (3 - 4 hrs each) using the same flight pattern each time were conducted annually from May-October with a total of 1-2 surveys by helicopter (Hughes Jet Ranger) and 4-6 surveys by fixed-wing aircraft (Piper Super Cub). In 1987 and 1988 fixed-wing surveys were also flown in January. The same two experienced observers performed all fixed-wing surveys, and one of these two observers participated in all helicopter surveys.

Methods employed in ground-based counts were similar to those described previously (Turner et al. 1981). Due to the rugged terrain of the study area, it was useful to initially locate horse bands from the air and plot their position on a topographical map. Although bands moved from day to day, they usually remained in a home range area, and once they were located it was possible to follow and monitor them from day to day. An effort was made to minimize intrusion on the horses and their daily activities. Foals were frequently lying in the brush and it was necessary to remain with a given band long enough to observe them moving several hundred meters. Under these circumstances, foals invariably stood up and moved. Our best estimate of the number of horses present in a given season represents the cumulative total of identifiable bands and individuals derived over a period of several weeks enumeration.

Population estimates were also calculated from fixed-wing aerial survey data for 1 May - 1 July (1987 - 1990) using the bounded-counts method (Seber 1982). This method estimates total abundance as $n=2N_m-N_{m-1}$, where N_m is the maximum count and N_{m-1} is the next largest count. Foals were not included in these counts, since significant foal loss occurred across time (i.e., between flyovers).

Mountain Lion

Data on the mountain lion population were obtained from track measurements, scats, tracking with and without hounds, kill site locations and visual identification of lions put at bay during tracking. The extremely limited availability of water insured that mountain lion tracks would appear regularly near springs, if lions were in the area. Track counts were used in the present study to determine relative seasonal densities of mountain lions (VanDyke et al. 1986). In 1987 and 1988 relative lion densities for a given month were determined by travelling the same 20 km of dirt roads in the MPWHT 6 mornings over a 2 week period and counting the number of separate sets of lion tracks which were present. The tracks were obliterated during each transit. Vehicular traffic on these roads was infrequent (no more than twice weekly). In addition to track frequency, detailed track analysis was employed to assist in identifying specific lions utilizing the MPWHT in the spring and summer. Track measurements were based on the procedure routinely used by the California Department of Fish and Game (Fjelline and Mansfield 1990). Three separate sets of front pad imprint width (center pad, widest part) were made for a given track observation. Tracks were followed until near-ideal pad imprint conditions, often present near springs, were located for taking measurements. Track shape, direction and location were recorded. One track was considered to be from a different individual than another track only if the average width difference was at least 3 mm in the same soil condition.

Evidence of mountain lion predation for a given carcass was based 1) canine tooth punctures in the neck and/or throat region of the carcass; 2) claw rake marks on the carcass; 3) canine tooth punctures on leg and skull bones of defleshed carcasses; 4) drag marks associated with the carcass; 5) covering of the carcass with brush and debris; 6) presence of track; 7) nearby presence of lion "scratch" marks, made when the lion uses its fore paws to draw back a small mound of soil underneath its body (characteristically done by males); and 8) lion feces containing horse hair. The presence of any one of signs 1-3 was considered minimum definitive evidence of mountain lion predation. The presence of any 3 of signs 4-8 was considered evidence of carcass use by lions. In the arid climate prevailing on the MPWHT in spring, summer, and autumn, the aging time of carcasses was estimated by regularly observing, for up to 6 months, several kills that had been located within one day of death. Scavenging by golden eagles (Aquilla chrysactos) and coyotes (Canis latrans) was common, and dismemberment of the carcass occasionally occurred within one month.

RESULTS

Estimates of the feral horse population in the MPWHT derived by a applying the bounded counts method to data from fixed-winged aerial surveys indicated <5.5% variation annually between 1987 and 1990, (Table 1). The mixed forested and open landscape yielded fixed-wing aerial counts which were 24-34% lower than total counts (minus foals) derived from accumulated ground and aerial surveys. However, the year-to-year comparison of the fixed-wing aerial surveys using the same flyover patterns provided a reliable index of population trend. The population estimates based on cumulative enumeration-identification data from combined, repeated ground and aerial counts showed <4.0% change annually between 1987 and 1990 (Table 2).

The 1986 data were based on approximately 300 hours of observation (15 May - 15 June), covering approximately 60% of the summer grazing range area. The same area in 1987 yielded a total count of 107 horses regularly utilizing this area. However, the proportional occurrence of the respective sex and age classes for the partial counts of 1986 did not differ from other years. Observation time for 1987 - 1990 was approximately 1,600 hours annually. The maximum number of individuals known to be in the population during this period ranged from 184 to 199. The composition of the population remained similar from 1986 through 1990, with foals and yearlings averaging 17.1% and 4.8% of the population, respectively. Males comprised 57.3% of the adults. The sex ratio (52.5% males) among 62 foals in which sex could be determined between 1987 and 1990 did not differ from unity ($p > 0.05$, X^2). The annual foaling rates were calculated as number of foals observed in a given year divided by numbers of mares more than 2 years of age. These rates, based on the year-specific ratio, were 53.6%, 60.7%, 59.3%, 53.9% and 50.0% from 1986 through 1990, respectively.

Annual foal survival, calculated as described above, averaged 26.3% across years (range = 23 - 32%). May to October foal survival, based on the number foals known to be missing by October, was 38-54% (Table 2). Of the total number of foals which were missing annually, an average of 45.8% disappeared between 1 May and 1 July, and 25.0% and 29.2% were noted missing in the intervals 1 July - 1 October and 1 October - 1 May, respectively.

Of the 48 foals which were noted missing between 1 May and 1 July during the study period, 52.1% of the carcasses showed use by mountain lion and 47.9% satisfied criteria for having been killed by lion (Table 4). Twelve of these 23 carcasses were fresh or well-fleshed and bore well defined claw-rake marks and tooth puncture wounds, usually in the head, neck and shoulders. The remaining carcasses ranged from moderately defleshed to completely defleshed and partially dismembered. Coat color, facial markings and lower leg markings usually remained recognizable for several months after death. When scavenger activity was not extensive, markings and portions of the skin and hair remained for at least 1 year. During the study period no evidence of predation by animals other than mountain lions was found and no evidence of predation was found in horse carcasses (n = 11) older than foals.

Twenty lion scats ranging from fresh to partly dehydrated were examined for horse hair during the study period. Hard, dry samples were not included. Of 16 scats found in May, June or September, 62% contained horse hair. None of the 4 scats found in January contained horse hair. Determination of the exact number of lions using the MPWHT between 1986 and 1990 was not possible, but a seasonal variation in lion density was apparent. Average track frequency (tracks/10 km ± S.E.) for May and June during the study period were 0.55 ± 0.26 and 0.61 ± 0.23, respectively, while counts for January averaged 1.28 ± 0.28 (Table 5). For the years 1986, 1987, and 1988, when extensive lion monitoring was conducted the minimum number of documentably different adult mountain lions regularly utilizing the MPWHT during the May - October period was 4, consisting of 2 males and 2 females. While it is possible that additional lions were present but not differentiable due to similar track size, it is highly unlikely that there were fewer than 4 lions. One of the two regularly present females was accompanied by 2 yearlings in summer 1987, and the other had a kitten in 1988. The use areas were different for the two males, which had tracks of 56.1 ± 3.0 mm and 62.3 ± 2.7 mm. (front center pad width ± S.E.), based on 19 and 18 sets of track recordings, respectively. The use areas were also different for the two females, which had tracks of 35.1 ±

1.9 mm. and 39.4 ± 2.4 mm., based on 25 and 19 sets of track recordings. One of the males regularly overlapped in area of use with the females. Photographic records were made of one female and one male put at bay by hounds during the study. Although pad size and location data collected in January 1987 and 1998 suggested the continued presence of these 4 lions that time, the presence of other lions precluded definitive conclusions in that regard.

In addition to carcasses of feral horse foals, the remains of 30 mule deer were found on the study area between 1987 and 1990. Mountain lion use was indicated in 14 of these carcasses, and 11 met the criteria for having been killed by lion. Most of the carcasses were from deaths during the winter and were discovered between May and July, often precluding conclusive confirmation of predation. Three fresh deer carcasses were found between May and October from 1987 to 1990, and 2 of these showed evidence of lion predation.

DISCUSSION

The data presented above demonstrate the existence of ongoing, seasonal predation by mountain lions on feral horse foals in the MPWHT. The exact incidence of predation is not known, as only circumstantial evidence exists that a mountain lion actually killed the foal in some cases. However, predation data combined with foal survival data suggest extensive predation on foals.

The present study has utilized a dynamic approach (foal loss across time) to determine foal survival, which provided survival data for 3 years. However, both the bounded-counts population estimates and the enumeration-identification population estimates showed <5.5% annual variation in population size with no apparent trend. These results suggest that foal survival estimates calculated time-specifically (within year) are probably valid. Studies employing both aerial and ground surveys with repetition over time can yield fairly accurate censuses (Bashore et al. 1990). The enumeration-identification approach yielded an average annual 5-year (1986 - 1990) foal survival rate of 29.7% (Table 2), which is similar to the 26.3% rate obtained using a horizontal basis. We conclude that less than 30% of the foals observed during the 5 years of the study survived their first year.

The observed annual foal survival rate in the MPWHT is less than one third of that observed in other horse populations studied to date (Perkins et al. 1979; Seal and Plotka 1983; Wolfe 1980; Wolfe et al. 1989; Garrott and Taylor 1990). Predation is reportedly insignificant in these other ranges, whereas 47.7% of the MPWHT foals known to be missing in May and June between 1987 and 1990 were documented as lion kills. Several factors also suggest that the documented incidence of predation is an underestimate of the actual incidence. Only 59% of the May and June foal losses were actually found as carcasses. Conceivably, a comparable fraction of the lion-killed carcasses were found. Considering the fact that mountain lions frequently cover their kills with brush, this percentage may be even lower. Furthermore, while definitive evidence of predation was found in only 23 of 28 foal carcasses, the cause of death in the remaining carcasses may or may not have been due to predation.

In a study of two separate feral horse herds inhabiting Assateague Island, Keiper and Houpt (1984) reported a foaling rate of 74.4% in the herd experiencing annual removal of most of the foals (for auction) as compared to 57.1% in the other herd, which was unmanaged. These findings suggest an inverse relationship between foal survival and foaling rates. However, despite poor foal survival in the MPWHT, the foaling rate in the MPWHT was within the range of foaling rates reported for several other western horse populations, including the Red Desert (Boyd 1979) in Wyoming, Stone Cabin Valley (Green and Green 1977) and Granite Range (Berger 1983) in Nevada, Challis in Idaho (Kirkpatrick et al. 1982; Seal and Plotka 1983) and Pryor Mountains (Feist and McCullough 1975; Perkins et al. 1979). Predation on foals has not been reported for these ranges.

While it may be argued from this comparison that predation does not influence foaling rates, the foal numbers in the present study do not account for foals which were born and died without being observed, and the incidence of this is unknown. Also, fecundity rates are age-specific, with younger adults showing lower fecundity (Wolfe et al. 1989). In the present study the age structures of the herd beyond 2 years of age was unknown. On the basis of these two considerations it may be that the foaling rates calculated for MPWHT are conservative.

It seems unlikely that the nutrition of the horse population was limited by forage availability. The MPWHT herd numbered less than 200, and on the basis of a range analysis for the MPWHT conducted by U.S. Forest Service personnel in 1987, provisional calculations indicated a summer-use carrying capacity of 280-350 horses for the MPWHT summer range (USDA Forest Service Tech. Report 1988). Horses were the only large grazing animal using the MPWHT during the study period, and the summer range was the site of greatest range use.

The peak foaling period in the MPWHT during the study was May and June. More than 80% of the foals which were counted were born during this time. Less than 10 foals were observed to be born between early July and late September. Foaling later than this was uncommon. This pattern is consistent with that reported for other ranges (reviewed, Kirkpatrick and Turner 1986; Kirkpatrick and

Turner 1983).

With a single exception all foal carcasses documented as lion kills were < 6 months old, 70% were estimated to be < 3 months old, and almost half of the annual foal loss occurred by early July. These data suggest that the lions utilized a window of vulnerability in killing foals, with the period of peak predation extending from late May through June.

Approximately 70% of the annual foal loss occurred between May and October. Track data have indicated the presence of specific lions in the MPWHT throughout the year, with a higher density of lions in winter than in summer. Thus it is likely that the lions utilize prey other than to foals between October and April. One important prey for mountain lions is mule deer. The Casa Diablo mule deer herd (approximately 500) migrates from higher elevation summer ranges in the Sierra Nevada into the MPWHT in late October and November (Thomas 1986). The herd winters there, usually vacating the area in April.

Preliminary data collected in spring and summer in the MPWHT from 1987 to 1990 revealed that 36.6% of the deer carcasses which were found bore definitive evidence of having been killed by mountain lions. While the seasonal incidence of lion predation on deer is unknown, the degree of decomposition of 90% of the carcasses suggested that the death had occurred prior to spring. Since most deer leave the area in the spring, and only 2 fresh deer carcasses showing predation were found between May and October over 3 years, it appears that most predation on large animals in this period is concentrated on foals. The incidence of lion predation on smaller mammals such as rabbits is unknown.

Successful use of track counts as an index of mountain lion population density has been previously reported (VanDyke et al. 1986). While track monitoring is only of limited use for identification of individuals in many circumstances, the May-October conditions in the MPWHT permitted this approach. The number of lions was small and the area was large, with little overlap in areas of use. Also, the extended period of monitoring revealed somewhat predictable route patterns for each lion. Consistent use patterns became apparent, with nearly exclusive use of certain areas by a given lion. Scats were examined macroscopically for evidence of horse hair. The greater frequency of lion tracks in January as compared to May or June may have been due to increased lion numbers or increased activity of existing lions. The former seems more likely, since variety in the size and location of tracks was also greater in January than in May or June.

Although it appears that fewer lions were present in summer than in winter, most of the predation on foals occurred in summer. This raises the possibility that the mountain lion population which utilizes the MPWHT exhibits a seasonal switching in type of prey. From May to October the prey appears to be primarily foals. Mule deer may then serve as an important prey from the time of their autumn arrival until their spring exit migration. This hypothesis is supported by the results of studies conducted by the California Department of Fish and Game (Taylor, personal communication). Of 23 mule deer equipped with radio collars on the winter range of the Casa Diablo Deer Herd Unit in 1985, 21.7% of the animals were killed by mountain lions within a span of 2 years. Although prey switching has been reported for other predators (Bergerud and Elliot 1986), the presently limited data on the lion and deer populations in the MPWHT preclude conclusions in this regard.

The existence of a continuing seasonal predation on horse foals by mountain lions to the extent observed in the MPWHT has not been reported previously. Whether this phenomenon is unique to the MPWHT or is present but simply not investigated in other ranges is unknown.

ACKNOWLEDGEMENTS

We thank M. Stranahan for partial funding of this study. We thank R. McCoy for aerial survey support and personnel of the Mono and White Mountain district of the U.S. Forest Service, specifically W. Svetich, W. Bramlett and D. Martin, for field assistance and tactical support. We thank T. Mansfield and D. Hunter of the California Department of Fish and Game and S. Stiver of the Nevada Department of Wildlife for administrative support and for training in lion monitoring. We thank R. Orisio, G. Orisio, R. Nelson and their associates, for help in monitoring mountain lions and C. London, D. Dohnel, W. Hyzer, B. Svetich, D. Bump, C. Bump, J. Roby and S. Link for their volunteer assistance in this study.

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TABLE 1. Aerial counts of feral horses[a] in the MPWHT.

Year	COUNTS[b] Max	2nd Highest	N	95% CL[c]	# of Counts
1987	111	108	114	111-168	3
1988	104	99	109	104-199	4
1989	109	99	119	109-299	5
1990	114	112	116	114-152	4

a Approximately 3 hours air time from a Piper Super Cub with 2 experienced observers.

b not including foals

c $N_m < N < [N_m - (1 - \alpha)\ N_{m-1}]/a$

TABLE 2. Size and composition of the MPWHT feral horse population from 1986 to 1990 based on accumulated ground and aerial counts made from 1 May to 1 July.

	Number of Horses (% of total)				
Age Class	1986[a]	1987	1988	1989	1990
Foals[b]	15 (15.9)	34 (18.5)	35 (18.3)	34 (17.1)	30 (15.6)
Yearlings	7 (6.5)	10 (5.4)	8 (4.4)	8 (4.0)	11 (5.8)
Two Year Olds	7 (7.4)	8 (4.3)	8 (4.4)	8 (4.0)	9 (4.7)
Adults	68 (70.2)	132 (71.7)	140 (77.6)	149 (74.8)	142 (73.9)
Total	97	184	191	199	192

[a] Partial count (see text).

[b] Based on the number of foals known to be born.

TABLE 3. Foal survival in the MPWHT feral horse population

Parameter	1987	1988	1989	1990
Yearlings present	10	8	8	11
Foals born	34	35	34	30
Foals missing				
1 May - 1 July	11	14	9	10
1 July - 1 October	6	8	5	5
Foal survival				
(May-Oct.)[a]	0.50	0.38	0.54	0.50
Annual survival[b]	--	0.24	0.23	0.32

[a] Calculated as $\frac{\text{foals born - foals missing}}{\text{foals born}}$

[b] Annual foal survival calculated by dividing the yearling count of a given year by the foal count of the previous year.

TABLE 4. Summer foal loss and mountain lion predation on foals in the MPWHT between 1 May and 1 July.

	1986[a]	1987	1988	1989	1990
Approximate foal loss (%)	26.6	33.3	43.7	28.1	34.5
Percent of missing foals found as carcasses	50.1 (2)	81.8 (9)	57.1 (8)	44.4 (4)	50.0 (5)
Percent of foal carcasses showing lion use	100 (2)	77.8 (7)	87.5 (7)	100 (4)	100 (5)
Percent of foal carcasses documented as kills	100 (2)	66.7 (6)	75.0 (6)	100 (4)	100 (5)

a Partial count (see text)

b As of 1 July, $\frac{\text{\# missing}}{\text{Total \# observed}}$

( ) = Number of carcasses

TABLE 5. Incidence of mountain lion track in the MPWHT

Month	Lion track frequency[a] (Tracks/10 Km ± S.E.)	
	1987	1988
January	1.35 ± 0.22	1.19 ± 0.33
May	0.71 ± 0.28	0.39 ± 0.23
June	0.57 ± 0.21	0.66 ± 0.24
September	0.35 ± 0.20	0.55 ± 0.40

[a] Based on 6 morning counts during a 2 week period, taken along the same 20 km of dirt road.