Environmental influences on movements and distribution of a wild horse (*Equus caballus*) population in western Nevada, USA: a 25-year study

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Wild horse populations in the American West have been heavily managed to regulate horse numbers since the inception of the Free-Roaming Wild Horse and Burro Act of 1971. The Montgomery Pass Wild Horse Territory (MPWHT) on the California/Nevada border is unique in the absence of human intervention there across the past 30 years. This has provided the opportunity to observe long-term patterns in the natural relationship between wild horses and their environment and to examine environmental impacts on the horse population and its activities, movements and distribution on the range. In this study multiple variables in the physical environment and in horse behaviour were monitored seasonally across 25 years beginning in 1987. Distinct summer (higher elevations) and winter (lower elevations) range use was characteristic for more than 60% of the population during the first 7 study years, with subsequent gradual but marked reduction in use of summer range. While approximately 20% of the population continued to annually use the historical summer range, the majority divided into two geographically and functionally separate subpopulations that resided year round in the historical winter range and adjacent areas on opposite sides of the MPWHT. Mountain lion predation on foals was restricted to the summer range, and exodus of horses from the summer range resulted in increased foal survival where horse subpopulations eventually resided. The long-term consequences of increased horse numbers in the MPWHT remain under continued study. The present study has shown that wild horses are highly adaptive and individually varied in response to environmental pressures. It has also demonstrated the value of long-term monitoring of wild horse populations to reveal underlying dynamics and their potential management implications.

**Keywords:** wild horse; environmental factors; population distribution; population dynamics; Nevada, USA

Introduction

Approximately 40,000 free-ranging wild horses (*Equus caballus*) inhabit public lands in the western USA ([USDI/BLM Wild Horse and Burro Program website](http://www.blm.gov/wo/st/en/prog/whbprogram/history_and_facts/quick_facts.html); History and Facts, 30 December 2013). Wild horses are protected by the Federal Free-Roaming Wild Horse and Burro Act of 1971 and are managed primarily by the United States Department of the Interior (USDI) Bureau of Land Management (BLM) with some involvement by the United States Forest Service (USFS), U.S. Fish and Wildlife Service (USFWS) and state agencies. Wild horse populations show annual

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rates of increase from 9% to more than 20% (Eberhardt et al. 1982; Turner and Kirkpatrick 1986; Wolfe et al. 1989; Garrott and Taylor 1990). Due to continued increase in these populations despite fixed or declining available habitat, the BLM has attempted to regulate wild horse numbers.

To enable effective population management, reliable information is needed on environmental factors and social dynamics influencing wild horse demography and distribution. It is known that movement and distribution patterns of various mega fauna, including ungulates, are affected by variables such as seasonal weather, food and water availability, social relationships and presence of other species (Honda 2009; Beschta et al. 2013). Despite the existence of nearly 180 federally designated free-roaming wild horse populations in the western United States (USDI/BLM Wild Horse and Burro Program website; History and Facts, 30 December 2013), there are few formal studies of these populations and their environment (Berger 1986; Feist and McCullough 1976; Turner and Morrison 2001). In part, this dearth has been consequent to the BLM round-up/adoption programme to achieve mandated limits of population size in these herds. Round-ups, with associated removal of horses from given populations, are routinely scheduled (approximately every 4 years), and may impact social organization and horse distribution. It appears that horse movements within and between range areas are in part dictated by social structure, and these movements can ultimately influence overall horse distribution (Turner et al. 1981; Berger 1986). Hence, populations experiencing periodic round-ups are unlikely to be useful for studies of long-term aspects of naturally driven horse distribution. An additional unnatural condition that exists for most horse populations is that they are not truly free-ranging but are, ultimately, limited by fences.

One notable exception to the horse removal/adoption and perimeter fencing issues is the Montgomery Pass Wild Horse Territory (MPWHT) on the central Nevada/California border. This horse population is not restricted by perimeter fences and has not experienced removals for the past 30 years. The latter is largely the result of a well-established pattern of mountain lion (*Felis concolor*) predation on these horses, with evidence of a pattern of seasonal prey switching by the mountain lions between horse foals and mule deer (Turner et al. 1992; Turner and Morrison 2001). This unusual relationship has prevented horse population growth, thereby obviating the need for removals. Although the prey switching phenomenon and lack of fences are not representative of western wild horse populations, these circumstances offered the rare opportunity to document the long-term functioning of a wild horse population in the absence of purposeful human interventions.

The purpose of this study was to examine environmental factors potentially influencing the wild horse population of the MPWHT and to determine the impacts of these factors on activities, movements and distribution patterns of that population. This report contains multi-variable data across 25 years and represents the longest continuous methodical study of a western USA wild horse population.

**Methods**

**Study area**

The MPWHT occupies 600 km² in Mono County, California, and Mineral County, Nevada centered at 38.5730 N, 118.3010 W (Figures 1 and 2). Elevations range from
1600 m in the peripheral portions of the MPWHT to 2600 m in the central portion, with lower elevations used by horses throughout the year, and upper elevations used May through September. October and May are usually transition months. The upper-elevation portion of the MPWHT is denoted henceforth as the “Key Summer Range” (KSR).

The boundaries of the MPWHT were originally assigned by BLM in 1972 and were derived from limited data of historical horse presence in the chosen areas. The boundaries are uniquely unfenced but are approximately delineated on three sides by paved roads, which some horses regularly cross. In 1987 the Inyo National Forest and BLM partnered in MPWHT management and formed a Coordinated Resource Management Planning committee, which adjusted the MPWHT map boundaries to more appropriately reflect horse use. Additional changes in horse distribution occurred during this study.

Most of the territory is located in sagebrush steppe and pinyon–juniper (Pinus–Juniperus) habitat (Figure 2A, B), with the predominant species in the latter being

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**Figure 1.** Montgomery Pass Wild Horse Territory (MPWHT) Map. The MPWHT lies on the California–Nevada border. Agency jurisdictions are USFS (green) and BLM (white). The three major horse areas are KSR (key summer range, i.e. upper elevations), Adobe Valley and Basalt (both historical winter range, lower elevations). Dotted lines within and outside the territory boundary represent additional horse use associated with the three main use areas. Hatched pink areas are grazing allotments (AV = Adobe Valley, BL = Black Lake, BS = Basalt). Closed squares are permanent springs. Open circles are seasonal springs. The blue line is Adobe Creek running into AV. Numbers are elevations (m), and triangle is highest point in MPWHT (2556 m). The lower left and right perimeters of the Territory roughly coincide with two paved roads (Routes 120 and 6). Relief aspect of map is courtesy of Google Earth.
pinyon pine (*Pinus monophylla*). The understorey is characterized by sagebrush (*Artemesia nova* and *Artemisia tridentata*), bitterbrush (*Purshia tridentata* and *Purshia glandulosa*) and rabbitbrush (*Chrysothamnus viscidiflorus*). Principal grasses are Great Basin wildrye (*Elymus cinereus*), western wheatgrass (*Agropyron smithii*), Indian ricegrass (*Oryzopsis hymenoides*), fescue (*Festuca occidentalis*), bluegrass (*Poa* sp.), and needlegrass (*Stipa* sp.). Various phorbs (especially *Lupinus* sp. and *Suaeda* sp.) are present depending on rainfall (Dedecker 1991; Spira 1991).

**Data collection**

This report provides quantitative and qualitative data derived from seasonal monitoring of wild horses, mountain lions (henceforth “lions”), mule deer and associated environmental variables across a 25-year period. These data are also correlated with information from Federal and State agencies on precipitation, forage and human activity across the study period.

The database for this report was derived from > 10,000 hours of field observation contributed by > 30 experienced individuals. Four to nine people worked in groups or worked separately and collectively logged up to 1300 field hours annually. In addition, > 300 hours per year were spent tracking lions with dogs between 1988 and 1995. Ground-based observations were systematic, with pairs of observers assigned to specific areas and waterholes. Each area was monitored in the same pattern over 1–2 days, and this pattern was repeated two to three times in a week. Work began in April and continued through October (sampling in August was sporadic except in 1993–1995). Systematic aerial surveys (3–4 hr each) using a replicated flight pattern were conducted from May to October at least once by helicopter and/or twice by fixed-wing aircraft as described previously (Turner et al. 1992). Seasonal supplementary and corroborative observations were provided periodically by field staff of the federal and state agencies assigned to the MPWHT.

The territory is seldom accessible by vehicle during winter. With the exception of monitoring in January 1987 and 1988 by the research team (comprising a 1-week ground survey and an aerial survey each year), winter surveys were limited to periodic observations by local research assistants.

**Animals**

Specifics of the methods for determining locations, enumerations and activities of horses and lions have been previously reported (Turner et al. [1991].

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Figure 2. (A) Image is looking east at horses in Adobe Valley (lower-elevation historical winter range at 1880 m.), with key summer range (KSR) in farthest-horizon background on left. Distance to centre of KSR is approximately 13 km. The White Mountains begin on far right, eventually rising to > 4600 m. (B) Image of horses at 2500 m elevation in typical KSR showing sage and pinyon/juniper habitat. (C) Representative horse band (trailing stud, three mares and foal). Colour of mare in centre (bay) represents > 40% of population. Colour of stud in rear (grey) represents < 10% of population. Background hill depicts intermediate-range elevation between lower and KSR areas.
Turner et al. [1992; Turner and Morrison 2001]. These methods are summarized below.

**Horses**

Reliable estimates of the horse population were generated from the collection of repeated aerial and ground observations made in 13 geographic subdivisions comprising the territory. In the most intensively studied areas complete enumeration was achieved on a regular basis with the use of individual horse and band cohort identification (Figure 2C). Observations were supplanted by periodic video and photographic records.

**Mountain lions**

Lions in this study were extremely stealthy (< 25 random physical sightings during the entire study), which required reliance on data based primarily on paw tracks, scratch marks, scat and radio-telemetry, with the latter performed from 1987 through 1995 (Turner and Morrison 2001).

Hunting lions has been banned in California since 1972. Although lion hunting occurs in Nevada, historically it has been infrequent in the MPWHT and was suspended from 1987 to 1995 (S. Stiver, Nevada Department of Wildlife, personal communication).

A given lion showed long-term regular use of a given area and limited overlap with other lions in areas of use. Identification of individual lions by track size proved reliable (Fjelline and Mansfield 1989; Smallwood and Fitzhugh 1993), with positive correlation of track-based identification and radio-telemetry. Most lion/horse water use was limited to seven springs, making regular circumferential inspection of the spring area useful for track monitoring.

Lions were radio-collared using California Department of Fish and Game (CDFG) procedures (Jessup and Clark 1986) and standard telemetry was employed (Telonics Inc., Mesa, AZ, USA; Telemetry Systems, Inc., Sarasota, FL, USA). Capture of lions was accomplished using a CDFG-trained tracker (R. Orisio) and dogs. Eight adult lions (three males, five females) were tagged between 1987 and 1995. Aerial and ground radio-telemetry was used to ascertain lion locations and common routes of travel, which was helpful in locating foal carcasses. Between 2001 and 2011, predation data were based primarily on foal survival rates (ratio of present-year yearlings to previous-year foals) and lion track.

**Mule deer**

The MPWHT serves as winter range for a portion of a migratory mule deer (henceforth “deer”) population (Casa Diablo herd). The summer home for most of this population is the eastern slope of the Sierra Nevada Mountains west of highway 395 at approximately 37.8 N and 119.1 W (north of June Lake and south of Lee Vining, CA; Jones and Stokes Associates, Inc. 1995). A portion of this herd annually moves approximately 50 km eastward from the Sierra Nevada to the middle elevations of the MPWHT in September/October and returns to the Sierra in March/April (Taylor 1988). Seasonal deer numbers in the MPWHT during the study were
estimated from collation of observations by the research team, local hunters and periodic aerial winter counts by the CDFG. The purpose of estimating mule deer presence in the MPWHT was to determine whether low deer numbers (i.e. insufficient lion prey) were a potentially limiting variable regarding lion presence and horse distribution.

Water

Information on water availability in the MPWHT was derived from precipitation data and observations of permanent and seasonal groundwater sources.

Precipitation

Mean annual precipitation in the MPWHT region is < 30 cm, most of which falls as winter snow. Maximum daily average temperature in July is 39°C, and winter lows average −10°C (Powell and Kliefather [1991]). A drought throughout the Great Basin, including the MPWHT, occurred from 1987 to 1993 (Morton et al. 1995).

A semi-quantitative scale for precipitation was generated from three sources. First, monthly precipitation records for each month of the study years were obtained from the U.S. Forest Service Fire Office remote automated weather station (RAWS) for the recording station closest to the MPWHT (Benton, California, which is < 3 km from the eastern MPWHT boundary). Second, the water level of a small (< 80 m diameter) seasonal pond (McNamara Lake) near the centre of the MPWHT was recorded across each May/June. Third, the activity of seasonal springs in the area was recorded each May/June because most precipitation occurred from February through April. A relative scale of 1–10 (where 10 = wettest) was established from these data to enable relative moisture assessment across the study. The 2006–2011 data did not include RAWS input.

Groundwater

There were seven permanent water sources within the horse use areas, which were active across the entire study. Four of these were used by horses year round and three (in the KSR) were used in all seasons except winter. There were also five seasonal water sources (dependent primarily on winter snowfall) that were available generally from April to July. Since water availability can markedly influence wildlife distribution, major water-site use by horses of known identity was field monitored in May/June and September/October from 1987 to 2004.

Forage and range condition

In June and September of 1990 and 1991 an assessment of range condition/forage was performed, and range carrying capacity was estimated for the KSR, riparian areas and selected winter-range areas of the MPWHT (USDA Inyo National Service unpublished files, Lee Vining, CA 1990/1991). The methodology employed standard walking grids and focused on key grasses and phorbs. Utilization was across five categories ranging from “no use” (0–5%) to “severe use” (81–100%), and employed the dot-count method for key species (USDA Inyo National Forest, range utilization protocol, Lee Vining, CA). As part of this assessment, both forage types and relative...
amounts were recorded. Preferences for forage types were determined by observation of horses eating and of plant types eaten and uneaten after horses vacated an area. Corroborative evidence of food preferences was obtained from a separate study of plant species present in faeces of MPWHT horses (L. Coates-Markle, personal communication).

Horse-dependent factors

The fundamental wild horse harem-band social structure (Turner et al. 1981; Berger 1986; Turner and Kirkpatrick 1986) is characteristic of the MPWHT population (Turner and Morrison 2001). Routine alerts, daily movements of harems, the timing of these movements and many daily social activities are usually directed or influenced by a dominant (sometimes referred to as “lead”) harem mare (Feist and McCullough 1976; Waring 1983). In this context, “dominant” refers to having an active leadership role more than behaviourally dominating other band members, although both were true for some mares. The role of this dominant mare in four well-identified MPWHT harem bands was studied from 1994 to 1996. These bands were chosen on the basis of ease of identification (colours/markings), band size (six to eight horses), and previously noted consistent presence of the same dominant mare and the same harem stallion. At least one foal was produced annually in each band. Each band was monitored in May, June and September to determine: (1) approximate daily travel distance, (2) travel routes taken, (3) grazing-site preferences, (4) dominant mare initiation of travel and (5) band tolerance to intrusion. The latter was based on estimated distance of a perceived intruder (people on horseback or in a vehicle) when a band alerted and moved away. The estimated distance which the band moved before stopping was also recorded.

Other factors

Grazing allotments

Three cattle-grazing allotments were located in the MPWHT and were in use from June through September when the study began. All were flat, sagebrush habitat in lower-elevation (1000–2000 m) parts of the range: Adobe Valley (fenced) in the western portion, Black Lake (fenced) in the southern portion and Basalt (unfenced) in the eastern portion. The wild horse use pattern of human-controlled water sites was monitored across the study.

Human presence

A variety of human activities occurred during the study, including public hunting, bird watching, range/animal monitoring by management agencies and researchers, educational/commercial wild horse observation trips and random recreational travel by the public through portions of the MPWHT on horseback or in motorized vehicles. The record of these activities across seasons and years was based on observations by researchers (primarily spring and autumn) and by employees of BLM, USFS and CDFG who periodically monitored areas of the MWPHT.
addition, anecdotal information was obtained from private citizens who regularly visited the MPWHT in association with private-sector uses noted above.

Data analysis

Eleven variables were examined either throughout the study or during selected periods within the study. The variables comprised horse numbers, lion numbers, mule deer numbers, seasonal horse movements, horse geographic distribution, lion geographic distribution, incidence of predation, water (precipitation/surface), forage (availability/use), horse behaviour and human presence. Data for each variable across the study were reported annually as a single value, with value units differing among variables. In cases where an average across multiple years was determined, values were presented as mean ± SD (Zar 1984). Database complexity and autocorrelation issues precluded application of time-series statistical analysis to across-study data sets. However, presentation of data graphically revealed well-defined temporal patterns, which facilitated interpretation. Data for water, forage and human presence employed a scale based on the highest-value year as 100%. Aspects of horse behaviour (dominant-mare role in band movement and intrusion tolerance) were assessed across 3 years for four specific harem bands, and the data were analysed separately for each band.

Results

Horse numbers

The MPWHT adult horse population during 1987–2006 averaged 137 ± 12 (range 103–169). An annual average of 28 ± 4 foals (range 18–35) were born in this period. Foaling began in mid-April and > 80% was completed by the end of June. The total horse population (all ages) varied considerably across the study, ranging from a low of 138 in 1995 to a maximum of 312 in 2011 (Figure 3). A notable period of population decrease followed by a period of increase occurred during the first half of this study. Horse numbers ranged from 184 in 1987 to 204 in 1991, declined markedly to 138 in 1995 and increased again to 220 by 2001. Also, between 2002 and 2011 the number of horses in all but one portion of the MPWHT varied < 12%. In that portion (Adobe Valley), which was historically a winter range area, horse numbers increased from 43 in 2005 to 180 in 2011 (Table 1). This increase began after cessation of cattle presence in the Adobe Valley grazing allotment. Abundant in water and feed, this site became accessible to horses via open gates and unmaintained fences and was devoid of lions. Many horses using this site became residents in this area year-round during this period.

Lion activity and predation

The total May–October lion population using the MPWHT was relatively stable at four to five animals from 1987 through 1991 and averaged 3.8 ± 0.4 across the entire study. It increased to eight animals in 1993, and then slowly decreased through 1999 to the original numbers. From 2001 to 2011 lion numbers did not exceed three adults (Figure 4). The year-round lion population never exceeded four adults. The number
Table 1. Horse numbers in the Adobe Valley portion of the Montgomery Pass Wild Horse Territory (MPWHT) (1999–2011).

| Year | Adult | Yearling | Foal | Total |
|------|-------|----------|------|-------|
| 1999 | 30    | 5        | 5    | 40    |
| 2000 | 28    | 3        | 6    | 37    |
| 2001 | 12    | 1        | 2    | 15    |
| 2002 | 43    | 3        | 10   | 56    |
| 2003 | 28    | 3        | 6    | 37    |
| 2004 | 41    | 4        | 7    | 52    |
| 2005 | 33    | 4        | 6    | 43    |
| 2006 | 69    | 5        | 8    | 82    |
| 2007 | 76    | 6        | 22   | 104   |
| 2008 | 82    | 9        | 14   | 105   |
| 2009 | 101   | 11       | 20   | 132   |
| 2010 | 126   | 16       | 26   | 168   |
| 2011 | 132   | 20       | 28   | 180   |

Figure 3. Annual total number of horses in the Montgomery Pass wild horse population. Numbers represent reliable estimate for all range areas (not complete enumeration).
of lions documented to have killed a foal in a given year ranged from zero to five, with two to three documented for the majority of years (Figure 4). The total number of lions killing foals was unknown.

During the telemetry portion of the study, 90% of radio-collar signals were located within the KSR. Male lions showed less reliable patterns of use and less overlap than females. From 1992 to 1995 it appeared that all but two lions using the KSR were collared. The exceptions were one female (with only three toes on the left front paw) and one male (largest pad recordings in the study, 66–68 mm). The regularity of these specific tracks in known travel routes and at watering sites allowed confidence in the identifications without collaring. No lion activity was observed in the historic lower-elevation horse winter range areas (lower-elevation, broad sage flats). Data for lion kittens during portions of this study have been previously reported (Turner and Morrison 2001).

Of the foals found dead across the study, 75–89% was attributable to predation by lions (Turner and Morrison 2001). Killed foals averaged 13.5 ± 4.93 annually during the most intensive lion-monitoring period of the study (1987–1995), comprising 45.1% of foals produced during this period. Foal age at time of predation averaged 1.5 ± 0.66 months (range 1 week to 9 months). Of 56 foals whose age at death could be estimated, 50.0% were killed during May, 32.1% in

Figure 4. Relationship of mountain lions and foal survival in the Montgomery Pass Wild Horse Territory (MPWHT). Data are based on annual assessment between May and September. The majority of predation occurred in the key summer range (KSR). Adult lion numbers and foal survival in the MPWHT: foal survival is presented as the ratio of current-year yearlings to previous-year foals expressed as a percentage, lion numbers are for individual lions documented by telemetry, track and/or sighting. The majority of lions were recorded in the KSR.
June, 10.7% in April, and 3.6% each in July and September. The predation rate averaged < 30% of the annual foal population between May and September from 2001 to 2011. Overall, 68% of all documented lion-killed foal carcasses were located within the KSR.

The use of present-year yearling to previous-year foal ratios to estimate predation rates in this study includes natural (non-predation) mortality. However, natural mortality in wild horse populations is generally low. Garrott and Taylor (1990) reported 3.2% foal mortality in horse populations (n = 243) using habitat similar to the MPWHT without regular predation. Also, in the most eastern sage-flat portion (Basalt) of the MPWHT, where horses did not mingle with other range areas and predation was absent, foal mortality averaged 4.3%. As the vast majority of foal mortality in the MPWHT was due to predation, the yearling-to-foal ratio was considered a viable estimate of predation rate. Annual survival rates estimated for foals averaged 0.48 ± 0.12 and ranged from a low of 0.22 during 1988–1989 to a high of 0.80 in 2009–2010 (Figure 4).

In the Adobe Valley portion of the MPWHT, which consisted of broad sagebrush flats with no demonstrable predation, foal survival ranged from 66.3% in the 1990–1994 period to 80.0% in the 2006–2010 period. In contrast, the foal survival rate in the KSR during these periods was 14.1% and 15.9%, respectively (Table 2). It is noteworthy that the horses using the Adobe Valley were a mixture of horses living year-round and horses seasonally using both the Valley habitat and lion-occupied habitat. As year-round use of the Adobe Valley increased after 2005 and fewer seasonal-use horses were present, foal survival rates were greater.

Based on individually identified yearlings observed the following year as 2 year olds, yearling survival averaged 0.90 ± 0.08, ranging from a low of 0.5 in 1994–1995 to a high of 1.0 in eight of the annual periods. Adult survivorship averaged 0.91 ± 0.02, ranging from a low of 0.81 in 1992–1993 to a high of 1.0 in seven of the annual periods. The horse population was at its lowest levels (< 160) in 1995, 1996 and 2000, averaging 82.1% of the 25-year average (Figure 4).

Table 2. Effect of horse redistribution on foal survival in segments of the Montgomery Pass Wild Horse Territory.

| Redistribution status | Years monitored | Foal survival* Yearlings / Foals (%) |
|------------------------|----------------|-----------------------------------|
|                        | Key summer range | Adobe                             |
| Pre                    | 1990–1994       | 3.0 / 21.2 (14.1)            | 3.6 / 5.6 (64.3)†   |
| During                 | 2000–2004       | 1.0 / 6.6 (16.2)              | 4.1 / 6.2 (66.1)†   |
| Post                   | 2006–2010       | 1.0 / 6.3 (15.9)              | 14.4 / 18.0 (80.0)‡ |

*Average of present-year yearlings divided by previous-year foals (eg., 1994 yearlings/1993 foals).
†Includes Adobe horses using key summer range periodically during summer and year-round Adobe horses.
‡Includes previous key summer range horses using Adobe year-round.
Mule deer presence

At the beginning of this study in 1987, the Casa Diablo deer population was estimated to be near 1500 (Taylor 1988; V. Bleich, CDFG, personal communication). Helicopter surveys between 2007 and 2011 revealed Caso Diablo deer population estimates from 2438 to 3009 (J. McKeever, CDFG, personal communication). The deer that annually migrate into and out of the MPWHT represent < 10% of the Casa Diablo herd (Table 3). Both resident and seasonal lions regularly preyed on this deer population throughout the study, and radio-telemetry data (obtained in the study and from CDFG files) indicated that some lions followed the deer herd during migration.

During the course of the study, the deer population that wintered in the MPWHT fluctuated but gradually declined (Table 3). Although deer carcasses and numerous deer faeces were found in the spring in years when snow melt was late (deer migration was delayed), there was commonly little evidence of deer other than scattered bones. Lion predation was documented as the cause of death in three freshly killed deer (in separate years) that had returned early in September to the MPWHT.

Seasonal horse movements

The relationship of horse locations and density across the study area is presented for several periods in the study in Figure 5. From 1987 through 1993, > 50% of the herd spent the months from May through September in the higher, cooler elevations (2400–2600 m) of the central portion of the range (KSR). For the remainder of the study period horse numbers in the KSR during these months gradually declined, with use by only 19% of the population in 2001 and only 13% in 2009 (Figure 5). During these same years the percentages of horses using lower-elevation (peripheral) areas (including some areas outside the demarcated MPWHT) were 41% and 12%, respectively. The period of greatest horse summer use of range locations outside the MPWHT was from 1995 to 2006 (Figures 5 and 6). The annual season-driven transition from KSR use to lower-elevation winter range use occurred on average between mid-September and mid-October. Some horses used the KSR area year

Table 3. Mule deer numbers using the Montgomery Pass Wild Horse Territory in winter.

| Year* | Number of deer |
|-------|----------------|
| 1987† | 225            |
| 1988† | 204            |
| 1992‡ | 280            |
| 1997§ | 148            |
| 2002–2009¶ | 128¶          |

*Deer were counted in December and January, and were located primarily in the key summer range area and lower elevations of southern portion of Montgomery Pass Wild Horse Territory.  
†Estimates derived from ground and aerial counts by research team.  
‡Counts by lion tracking team.  
§Estimate from aerial count (private fixed-wing).  
¶Average of annual helicopter-based counts by CDFG (unpublished agency files) from 2002 to 2009.
round, wintering at lowest KSR elevations, which were generally near the snow line. The spring return from winter range to summer range occurred between mid-April and mid-May for most horses. More than 90% of the horses that ceased using the KSR across the study wintered inside the MPWHT. However, between May and late September from 1995 to 2011, these horses distributed themselves across range areas both inside and outside the MPWHT (Figure 6).
Surface water and precipitation

Snowfall in the MPWHT occurred annually and variably from November through March. When snow was present, horse travel was unrestricted. However, horses generally favoured grazing in proximity to the snow line and followed the snow line upward as spring melting occurred.

MPWHT horse movements and distribution in summer and autumn were linked to locations of permanent and ephemeral (seasonal) springs. This was of less importance in winter when snow was present.

Across the study, the Benton RAWS data showed that the months averaging greatest precipitation were January (7.0 cm), April (8.1 cm), August (9.5 cm) and November (13.8 cm). Semi-quantitative precipitation estimates from McNamara Lake (pond) and observations from annual seasonal spring activity showed a similar across-years pattern to the Benton RAWS data. Mid-summer presence or absence of seasonal water sources also correlated with the above data. Occasional summer thunderstorms provided short-term pools of water across the range, but these were of insufficient duration to impact horse distribution. In summary, water in the MPWHT was highly variable across the study, with dry periods in the 1987–1991 and 2000–2004 intervals and the wettest period from 1993 to 1996 (Figure 7).

Figure 6. Montgomery Pass Wild Horse Territory (MPWHT) horse use of non-key summer range (KSR) areas. Use outside the MPWHT primarily includes areas east of Basalt and west of Adobe Valley.
Range condition

The years 1990 and 1991 were among the driest during the study and were also the years of greatest horse numbers using the KSR. The period in which most of the redistribution occurred was after 1993 and was one of markedly greater KSR grass quantity than in 1990–1991, and so represented a conservative estimate of possible impact of KSR food supply on horse numbers or their redistribution (Figure 8).

The focus of utilization assessments was on areas within 2 km of water sources. Utilization varied widely across assessed sites, with the majority being from 10–60% (“slight” to “moderate”). The average 1990/1991 KSR utilization was 42% near water and 28% in outlying areas, with regular horse presence during that period averaging 119 horses. Based on these data and allowable utilization of 35% without impairing sage/grassland habitat health (Holechek et al. 2004), the KSR carrying capacity was estimated to be approximately 340 horses. Selected non-KSR areas at lower elevations were concurrently assessed and averaged 30% utilization. The monitored areas comprised < 15% of the total territory. However, significant portions of the unmonitored areas were represented by extreme alkaline conditions and very poor range quality.

The portion of the horse population known to use the KSR during the 1990/1991 range assessment was < 150 animals. The non-KSR range areas were more than eight-fold larger and considerably lower in horse density than the KSR (with the exception of Adobe Valley). The supply of preferred feed in the portions of these areas regularly used by horses appeared sufficient in quantity throughout the

![Graph showing precipitation and KSR grass quantity relative to population using KSR.](image-url)
study based on periodic subjective assessment whenever researchers passed through them. While a checkerboard pattern of feed quantity was observed throughout the MPWHT, the overall range conditions where horse use was common were similar in utilization to that observed in the 1990/1991 KSR range assessment. Available grass and phorb types were generally similar to those in the KSR.

As part of the MPWHT horse redistribution, rapidly rising horse numbers in one range area (Adobe Valley) reached 180 animals in 2011. The Adobe Valley horse numbers were 53% of the carrying capacity estimated for the KSR in 1990/1991 (Figure 8). Horses that were regularly present in Adobe Valley also used adjacent lower-elevation range areas, which comprised an overall size approximately four-fold larger than the Adobe Valley flatland. In Basalt and other lower-elevation portions of the MPWHT the horse numbers never exceeded 60.

In 1995, 2002 and 2010 utilization inventories were performed in selected locations in the KSR, Basalt and Adobe Valley. General range condition was considerably better in Adobe Valley (Adobe Creek flows into it) than in Basalt, which is approximately 1000 m. lower in elevation and has less annual precipitation and only two permanent springs. Utilization averaged less than 40% in all

Figure 8. The relationship of key summer range (KSR) horse use and carrying capacity in the context of the Montgomery Pass Wild Horse Territory (MPWHT) horse population. As KSR horse numbers decreased, use outside the KSR increased. Total population range use is presented as a percentage of KSR carrying capacity. As total population increased across years, it remained < 80% of carrying capacity for KSR alone, suggesting that considerable population growth can continue without reaching carrying capacity.
range areas in all years assessed except for 2010 in Adobe Valley, where it averaged 56%. Usage decreased as distance from water sources increased. KSR areas showed predominately “light” use from 2000 forward, and range condition steadily improved.

**Grazing allotments**

One allotment (Black Lake) was fenced and remained in seasonal livestock use throughout the study. A second allotment (Basalt) was unfenced and was unused by livestock after 2003, although water troughs within it were filled through 2006. Horses were permitted to graze with cattle on this allotment throughout the study. The third allotment (Adobe) was fenced and was active through 2005. Adobe Creek is a permanent water source that flows year round through the allotment. It is < 3 m wide and < 1 m deep and disappears within the allotment, irrigating an 8-km² open flat of grass and sedges. The upper portion of Adobe Creek (approximately 1.5 km length) is unfenced and was always accessible to the horses. However, the associated graze-rich allotment was fenced, and horses generally did not have access. Both the upper portion of the creek and the portion within the allotment (when gates were occasionally left open) were used by horses, with their preference being the latter. After 2004, the fencing was not maintained and horses had full access to the allotment year round via broken, unrepaired fences and open gates.

**Human presence**

Wild horses are generally averse to human presence, so the possible impact of human activities on horse movements and distribution was examined. Recreational activity, small-scale mining, seasonal (May–September) livestock grazing and hunting occurred in the MPWHT for decades before and during this study. There was very little human presence from October through April. A significant aspect of the livestock grazing has been the development of existing water sites and establishment of water troughs in areas naturally without water, with potential impact on distribution of horses and other species. In addition, fencing associated with some water sites and with grazing allotments can influence animal distribution and movement. In general, the horse range-use patterns related to the above factors were well established and relatively consistent at the onset of this study.

In 1986 a local company began an annual series of 4-day educational (most associated with university extension programmes) trips into the MPWHT from mid-May through mid-June. These trips generally accommodated 8 to > 20 guests and were focused on observing wild horses in their peak foaling/breeding period in the KSR area. In 1993 a second company began a similar programme in the KSR area. While these trips were designed for minimal intrusion on the horses (i.e. use of binoculars and no direct approach), they represented a marked increase in human presence (Figure 9). In some years between 1994 and 2007, more than 200 guests travelled into the KSR. In addition an undetermined level of local use (motorized vehicle and horseback recreational activity) occurred during this period.
Horse-dependent factors (band movements and behaviour)

Initiation of band movement

Daily movements by all four specifically monitored bands to and from water were common early in the day, especially in summer months, and were usually initiated by the dominant mare. The dominant mare also initiated an overall average of 84.0 ± 7.6% of observed cases of a band leaving a site to travel for any reason (Table 4). In many cases in which the harem stud or another band member initiated travel, the dominant mare led the travel soon after movement began. In addition to initializing daily band movements, the dominant mare usually led the band to grazing sites and chose when to stop. This was regularly observed in all four of the monitored bands.

Grazing-site preferences

Three of the four dominant mares exhibited repeated, and in some cases regular, visits to one or more particular sites. Predominance of one or two grass species at a given site was common. Analysis of fresh faecal samples collected at grazing sites indicated that the most commonly consumed plant species were Great Basin wild rye, lupin, Indian rice grass, fescue, needle grass and various phorbs. Rushes and sedges were used in riparian areas (L. Coates-Markle, personal...
communication). These findings were confirmed by spotting-telescope observations of horses ingesting feed in the four selected target bands. Invariably the dominant mare was noted to ingest the predominant grass type of the site that she had chosen for grazing. These forage species were present in varying amounts across most of the MPWHT.

Intrusion tolerance

The dominant mares in two of the four regularly monitored bands were markedly less tolerant of intrusions than the lead mares of the other two bands (Table 4). When travel occurred, the less tolerant bands travelled significantly further before grazing was resumed. The estimated average intrusion-tolerance threshold for the two bands with lowest intrusion tolerance was 725 m, and these bands travelled an average of 2.4 km before stopping. The average intrusion-tolerance distance for the more tolerant bands was 175 m, and they travelled an average of 0.85 km before resumption of grazing. Both of the low-tolerance bands permanently vacated the KSR (one in 1994 and one in 1995), and both of the high-tolerance bands remained in the KSR through 2004. They were not monitored thereafter. Incidental observations of dominant mares in various other bands in subsequent years revealed a wide range of tolerance to intrusion among bands, with vigilance being greatest during the foaling season. The dominant mare and stallion in specifically monitored bands did not change during the monitoring periods, although changes in band membership, primarily among younger adults, did occur.

Table 4. Response of Montgomery Pass Wild Horse Territory (MPWHT) harem bands to intrusion by humans or other horses.

| Harem band | No. of horses per band | Incidence of dominant mare initiating travel (%) | Average estimated Intrusion-tolerance distance (m) | Average estimated travel-distance (km) | No. of events observed |
|------------|------------------------|-----------------------------------------------|-----------------------------------------------|---------------------------------------|------------------------|
| A          | 8                      | 45 / 52 (87)                                  | 202 ± 76                                       | 1.0 ± 0.4                             | 14                     |
| B          | 6                      | 32 / 43 (74)                                  | 620 ± 122                                      | 2.1 ± 0.6                             | 16                     |
| C          | 8                      | 37 / 40 (92)                                  | 805 ± 119                                      | 2.4 ± 0.6                             | 10                     |
| D          | 7                      | 39 / 47 (83)                                  | 163 ± 63                                       | 0.7 ± 0.3                             | 13                     |

1The stallion and lead mare in a given band remained with that band during the observation period 1994–1996.
2Per cent of travel events initiated by dominant (lead) mare with or without apparent intrusion by humans or other horses.
3Estimated minimum distance (mean ± SD) permitted between grazing band and intruder before alerted band moved off (distance determined by reticle binoculars in 25-m increments).
4Denotes travel distance (mean ± SD) in response to intrusion before band stopped and reinitiated grazing (distance estimated by reticle binoculars and topographical map in 0.1-km increments).
5Applies to both intrusion-tolerance and travel-distance columns.
Band travel

Although daily travel distances varied both within and between the above four bands, some bands generally travelled greater distances than others. Two of the studied bands (one high-tolerant, one low-tolerant) usually travelled < 5 km across 2 days and remained within 2–4 km of preferred water. The other two bands travelled > 8 km daily, often between two distant watering sites. Each band exhibited preferred travel routes and travel patterns tended to be habitual rather than random.

Discussion

It is known that wild horse populations in the western USA generally move to higher elevations in the spring, following the annual green-up and its associated high nutrition (Berger 1986). The majority of horses remain in the cooler upper elevations through the summer. This phenomenon has been observed annually in several horse ranges by the author. This pattern was extant in the MPWHT herd for a number of years before the present study (Mennick 1979) and continued during the first 7 years of this study (1987–1993). However, progressive changes in the MPWHT horse distribution developed in the remainder of the study. This redistribution eventually involved approximately two-thirds of the herd and consisted of decreased KSR use with associated increased summer (and eventual year-round) use of historic lower-elevation winter range. In addition, use of areas outside the historically mapped territory increased. As noted previously, some horses used KSR at its lower elevations (near snow line) throughout the winter.

These alterations have persisted to the end of the study, with a resultant division of the original seasonally congregating population into three essentially separate subpopulations: (1) KSR, (2) Adobe Valley and (3) Basalt. The MPWHT topography and limited water sources have fostered complete isolation of the Adobe Valley horses from the Basalt horses. The former are on the west side, and the latter are on the east side, separated by 18 km of rough terrain with nearly 2 km vertical relief. While the KSR horses do winter at lower elevations, these are generally more north and south, separate from the east-side and west-side subpopulations. Nonetheless, some horse bands that had annually used the KSR in the first decade of the study had also routinely wintered in the Adobe Valley and its surrounding hills. Since the KSR and Adobe Valley areas are within 6 km of each other, occasional mingling of some KSR horses with Adobe Valley horses continues.

Some increase in summer use of the historical winter range had been observed as part of horses gradually vacating the KSR by the late 1990s. However, an unusual aspect of the redistribution was the dramatic increase in numbers in Adobe Valley from 2006 to 2011. This cannot be explained solely by redistribution from the KSR to Adobe Valley. Whereas a number of individually identified horses and bands that had regularly summered in the KSR were present in Adobe Valley after 2005, previously identified bands from adjacent non-KSR range areas were also moving into the Adobe Valley to benefit from the high-quality grazing and water availability. Furthermore, with no incentive to leave, they were remaining there year round. While this adaptation is not surprising, the rapid rate of ingress is unexplained.
The number of horses summering in the Adobe Valley was 40–52 between 1999 and 2004 and was 43 in 2005, which was the final active year of that grazing allotment. Between 2005 and 2011 the horse numbers there rapidly and steadily rose to 180 (more than half of the MPWHT population). Other range areas showed small increases in horse numbers but never exceeded 60. An interesting question is how numerous bands of horses occupying different range areas multi-kilometre distances from each other and in some cases > 15 km from Adobe Valley become aware of the availability of grazing/water there.

A factor that probably contributes to the marked increase in horse numbers in Adobe Valley is the absence of predation in that range area. Although there was no predation in the Adobe Valley at any time during the study, the high foal survival rate evidenced itself more obviously as the numbers of horses (and therefore mares) in that area markedly increased. The relationship across years of decreasing KSR use to increasing population of surviving foals is apparent when these measures are plotted together (Figure 10).

Although the impetus for redistribution may be complex, the data have revealed some potential factors to be more likely candidates than others. Based on pattern comparisons across years for various factors in relation to horse use of KSR, it is unlikely that water availability or feed availability influenced redistribution of horses. Travel distances to water were not different inside and outside the KSR and in some areas were closer in the KSR. In the driest years the usual seasonal water sources were

![Figure 10](image)

Figure 10. Relationship of reduced key summer range (KSR) use on whole-population foal survival. KSR is the primary area of lion use and predation. Foal survival is presented as the ratio of current-year yearlings to previous-year foals expressed as a percentage. Foal survival data are for the entire Montgomery Pass Wild Horse Territory (MPWHT) population.
absent, so yielding in some years greater horse density in the proximity of the permanent water sites. It appears unlikely that this was related to horse redistribution because there were permanent springs in the KSR, and horse numbers remained high in the KSR during the driest years of the study when seasonal water sources were dry. Unusually elevated precipitation from 1993 through 1996 (except 1994) may have facilitated redistribution. The presence of many ephemeral water sites and improved feed in normally unproductive areas may have enabled horses under pressure from other sources to leave the KSR and not return to it in the following years. It is noteworthy that the exodus from KSR began during the wettest period of the study (Figure 7).

On the basis of the range assessments performed across the study it appears that food availability was not a significant factor in horse redistribution. Assessment of range condition and grass utilization was not frequent or extensive during the study, but heavy or severe utilization was rarely observed and most use was light to moderate. KSR use was maximal in the early years of the study, when KSR feed was least abundant. However, the estimated carrying capacity of 340 for the KSR always exceeded the seasonal demands in the KSR by at least two-fold. Preferred grasses and phorbs were present in a number of range areas outside the KSR. Although it is possible that depletion of a favoured plant species could lead to eventual horse movements out of the KSR, the large scale of the KSR exodus makes this unlikely.

The horse redistribution has clearly applied more grazing pressure on the lower-elevation range areas, and a careful assessment of carrying capacity in these areas is warranted. However, the entire horse population was approximately 312 in 2011, and this number is < 80% of the carrying capacity determined for the KSR alone in 1990/1991. Considering that these years represented one of the driest periods in the study with the majority of the population summering there, it appears unlikely that the current horse numbers are approaching the carrying capacity of this much larger range area. Furthermore, most of the range areas experiencing increased horse numbers have not seen dramatic increases in use. Whereas a large increase in use might be expected eventually in Adobe Valley, the presence of its large riparian area with quality replenishing forage and large adjacent range areas may moderate range impact as horse numbers rise. Nonetheless, the high rate of foal survival in the non-predation areas that hallmark the horse redistribution raises this issue for the future, making continued monitoring wise. For example, extended heavy range use could potentially deplete seed stock, with resultant lower carrying capacity and prolonged recovery time even with fewer horses present.

In addition to geographic redistribution during the study, an increase in geographic dispersal outside the historical map-delineated MPWHT was observed (Figure 8). This was possibly because of the combined increase in the number of horses migrating into lower-elevation range areas and the consequence of the lack of predation in those areas resulting in increased foal survival (i.e. further population growth). Hence, horses probably spread out to accommodate increasing density. The increased local dispersal may explain in part why the utilization in some areas did not increase proportionally to increased horse numbers. It is noteworthy that in both areas where horse presence outside the MPWHT was significant there was a major water source adjacent (within 1–2 km) to the territory boundary and no restrictive fences.
Regardless of the fluctuations in deer numbers during the study, the annual winter presence of > 100 deer in the MPWHT in every year in which such observations were recorded suggests that there was sufficient winter prey for the estimated two to four lions that resided there year round. It therefore appears unlikely that deer presence or numbers influenced the occurrence of predation on horses or horse redistribution.

Two factors that did correlate negatively with horse exodus from the KSR were mountain lion activity and level of human presence. The association is apparent when these three variables are presented in a single figure (Figure 11). Lion numbers were maximum at the time when horses began leaving the KSR. However, lion presence and predation on wild horse foals was reported to have occurred regularly for at least 20 years before this study (Mennick 1979). Nonetheless, increasing lion numbers may have been a factor in stimulating horse redistribution. Clearly the mountain lion predation on foals has played a critical role in moderating growth of the MPWHT horse population during this study.

The relationship of human presence to lion numbers was not a focus of this study. However, it is apparent that both lion and horse numbers decreased as human presence increased. Although human presence in the KSR may have stimulated both horses and lions to leave, it is possible that the lions left because the prey left. Conversely, the prey may have left because the predator number was increasing. The

Figure 11. Relationships of human presence, horse key summer range (KSR) use, and lion numbers in the Montgomery Pass Wild Horse Territory (MPWHT). Human presence (May–September) is presented as per cent of its highest year. Horse KSR use is presented as per cent of the total population using the KSR. Adult lion numbers are presented as the percentage of the maximum single-year lion number.
present database cannot resolve the cause–effect relationship of these variables. Regardless, a relevant consequence of horse redistribution to range areas of poor lion habitat (lower-elevation sagebrush flats) has been the marked increase in population foal survival and overall population size (Figures 3 and 10). Interestingly, predation has continued on horses that remained in the KSR, and the foal survival of Adobe Valley horses is four-fold greater than for current KSR horses (Table 2).

In the first 3 years of the study (1987 through 1989) > 70% of the MPWHT population summered in the KSR. During this period regular human presence in May and June was increasing. It may be that in the face of this increase some horse bands reached a threshold of tolerance for human presence. The fact that the two bands of horses with the lowest intrusion tolerance permanently vacated the KSR supports this view. The fact that the focus of human activity in the KSR was during the foaling/breeding period may have intensified any human contribution to the decrease in horse numbers there.

Although the observations of dominant-mare roles in this study were limited formally to four harem bands, the findings were robust and were not contradicted by any other subjective observations across the study. Clearly, the choice of a given grazing site and when to leave it was predominantly made by the dominant mare. Invariably in bands with the same dominant mare across several years, the travel routes and the favoured grazing areas were similar from year to year. Based on the observation that dominant-mare decisions strongly influenced band movements in this study, it appears likely that dominant mares also played a significant role in population redistribution. While all four of the individually identified and monitored harem bands in this study maintained stable band membership among the adults, subjective observations across multiple years and numerous bands revealed considerable variation in stability among bands.

**Summary and conclusion**

In summary, annual monitoring across a 25-year period has revealed a gradual but marked redistribution of horses in the MPWHT. This redistribution has involved horse movements both within and beyond the historical map boundaries of the territory, and has led to three sub-populations, which have become in essence geographically and functionally separate. Neither food nor water were limiting in the KSR, and were therefore unlikely to be a stimulus for these changes. However, several separate years of extremely wet conditions may have facilitated larger-scale, long-distance summer transitions from KSR to lower elevations and the retention of horses at lower elevations thereafter. An additional contributory factor for the latter may have been increased availability of feed and water associated with cessation of commercial use of lower-elevation grazing allotments during the time of horse exodus from the KSR. Two factors that were temporally well correlated with the marked reduction in KSR use were increased KSR mountain lion predation and increased annual KSR human presence during the spring foaling/breeding period. In the context of social dynamics and in view of the fact that some horses continued to use the KSR while many did not, it is hypothesized that the horse bands that were more tolerant of lion and human presence remained there.

This study has documented aspects of the dynamics of the MPWHT and the impacts of these dynamics on wild horse activity and distribution there. Many
variables and their complex interplay can potentially influence geographic horse movements and distribution. However, clear associations of some variables with horse redistribution became apparent across numerous years of study, strongly suggesting greater or lesser influences. The across-years database has shown that the horses are sensitive to environmental pressures and are adaptive at both the individual level and population level. It is interesting that despite the absence of intrusive management in this horse population, the effects of human presence (e.g. visitation, observation, grazing allotments) appear to have influenced horse distribution. In this case, however, it is the horses that are making the choices of where, when and why, and the human factor is simply one component of the ecosystem dynamic. The presence of long-term human observation in the MPWHT has enabled documentation of numerous dynamics moulding this wild horse population. It has also revealed that the wild horse/mountain lion relationship there is presently undergoing significant change. If the evolving horse distribution pattern on the range continues to thwart the extant predator–prey relationship, continued horse population growth will certainly require more active management to assure habitat well-being.

A stipulation in the Federal Wild Free-Roaming Horses and Burros Act of 1971 (Public Law, 92–195) is that wild horse populations be managed in a manner that “achieves and maintains thriving natural ecological balance on the public lands”. The MPWHT is the only well-studied wild horse population in the western USA that has probably satisfied this stipulation across the past 30 years, considering its unique, natural status that presently exists. Continued monitoring of the MPWHT can strengthen its value as a reference base for use in management considerations for other wild horse populations. In the presently shifting ecological landscape of the MPWHT this monitoring will also aid the exploration of management options for the MPWHT.

The study of the MPWHT was intended to explore wild horses in a “free-roaming” state, based in part on the absence of perimeter fences there. However, the dramatic horse influx associated with the downfall of the exclosure fence in the Adobe Valley grazing allotment strongly shows how fences interfere with the expression of “free-roaming”. On a much larger scale, the majority of wild horse populations in the western USA are restricted by perimeter fences and often by internal fences as well. This situation is clearly exhibited in the current problems facing the BLM with overpopulation of horses on fixed ranges and the consequent habitat loss. Using the MPWHT as a reference base for wild horses in natural balance with their environment shows that wild horses in most populations are not free-roaming and are not in a natural balance. Assuming that removal of fences is not an option, achieving a natural balance will require major conceptual changes in wild horse management.

As noted in the Introduction to this study, most wild horse populations in the western USA increase 9–20% annually, making population management in these fixed habitats extremely difficult. The MPWHT has had the natural benefit of ongoing predation to limit horse population growth. However, most wild horse populations do not experience significant predation, and introduction of predators is not a publicly acceptable or realistic solution. Therefore, most populations must be intensively managed by regular human intervention. There are only two permissible (i.e. non-lethal) means available to accomplish this under the Wild Horse and Burro Act of 1971: physical removal of horses from the range or reduction of their fertility rates. Although the former has been the predominant and intensive path, it has chronically lagged
population growth rates (USDI/BLM Wild Horse and Burro Program website; History and Facts, 30 December 2013) and has the disadvantages of periodic disruption of social structure and imposition of gene pool biases. The most successful approach for limiting reproduction has been contraceptive vaccines (Turner et al. [1997, 2007, 2008; Kirkpatrick and Turner [2008]; Ransom et al. [2011]), which have been used in wild horses for more than 20 years and do not have the disadvantages associated with horse removals. More recently, fertility control has become a greater focus for large scale wild horse management application (Turner and Rutberg [2013]).

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