BLM Research Proposal Format

A. COVER PAGE

US Department of Interior
Bureau of Land Management
Wild Horse and Burro Program

Proposal for Research Effort

1a. Demography of two wild burro populations in the western USA
TITLE OF PROPOSAL (90 Character Maximum)

1b. Schoenecker, K.A.; King, S.R.B.; Zeigenfuss, L.C.; Searle, K.R.
INVESTIGATORS (Principal-Investigator LAST NAME, FIRST NAME; Co-Investigators LAST NAME, FIRST NAME)

2a. Dr. Kate Schoenecker
NAME OF PRINCIPAL INVESTIGATOR (PI)

2b. (blank)

2c. Ecologist and Affiliate Faculty
POSITION TITLE

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2e. USGS and Colorado State University
INSTITUTION AND DEPARTMENT

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Ecosystem Science and Sustainability, CSU, 1213 East Drive, Ft. Collins, CO 80523

3a. THIS PROPOSAL IS A: (Mark one only) X NEW APPLICATION ___ CONTINUATION ___ UNPLANNED EXTENSION

3b. FOR COMPLETION, A FUNDING REQUEST IS:

INCLUDED and REQUIRED	INCLUDED but NOT REQUIRED	NOT INCLUDED
X		

3c. AMOUNT OF FUNDING REQUESTED:

FIRST YEAR	SECOND/THIRD YEAR	FOURTH/FIFTH YEAR
$ 173,659	$135,332/135,332	$141,497/210,601

3d,e. DATES OF PROPOSED STUDY:

START	END	
August 2015	December 2020	Total: $796,421

AGREEMENT: It is understood and agreed by the undersigned if this proposal / application is approved, whether or not a grant is made, it will be according to the terms of the proposal and the stipulations set forth in the accompanying instructions. In addition, a written agreement appropriate for the nature of the proposed work (e.g., Memorandum of Understanding, Assistance Agreement, Task Order, letter of agreement) will be required to outline the obligations of the researchers and the BLM in the conduct of the study.

PRINCIPAL INVESTIGATOR ASSURANCE: I agree to accept responsibility for the conduct, completion and reporting of the study proposed here and to provide the agreed upon progress and final reports.

4a. SIGNATURE OF PRINCIPAL INVESTIGATOR: ______________ DATE: 10-12-2015

CERTIFICATION AND ACCEPTANCE: I certify that the statements made in this application are true and complete to the best of our knowledge, and I accept the obligation to comply with the above agreement. I understand that the Principal Investigator and his/her department will be responsible for any expenses incurred by this project which exceed the approved funding amount.

4b. OFFICIAL SIGNING FOR ORGANIZATION: ______________ DATE: 10/13/15

4c. ADDRESS: 2150 Centre Ave, Bldg. C
Fort Collins, CO 80526

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4e,f. PHONE: 970-226-9100 FAX: 970-226-9230

B. RESEARCH OBJECTIVES

BLM Wild Horse and Burro Program
Proposal for Collaborative Research Effort

Name and Address of Applicant or Applicant Organization:
USGS, Fort Collins Science Center
2150 Centre Avenue, Bldg. C
Fort Collins, CO 80526

Title of Project: Demography of 2 wild burro populations in the western USA

ABSTRACT:
Burros are a domesticated variety of the African wild ass, brought to America by the Spaniards. They are protected under the 1971 Wild Horse and Burro Act (Public Law 92-195). There is remarkably little published literature on the wild burro, despite our long association with them as a domesticated species. Almost all the research conducted on wild burros was in the 1970s and 1980s, and there are even fewer studies on the African wild ass. Management of burros has been impaired by this lack of knowledge, particularly because what little research has been conducted indicates that they are both socially and behaviorally very different from wild horses, and exhibit different habitat use and diet. The National Academies of Science (NAS) recommended acquiring population ecology information on burros to better inform their management (National Research Council 2013). We propose to conduct a descriptive study of the demographic parameters of wild burro populations inhabiting 1) a Sonoran Desert ecosystem in Arizona, and 2) a badlands ecosystem in Utah. We propose to measure fertility, fecundity, recruitment of foals, age-class survival and mortality of burro jennies, habitat selection, movement ecology, and habitat range of jennies. We propose to build a state-space Bayesian model to predict the environmental attributes driving survival and population growth of wild burros, as well as a habitat selection model.

Name, official title, department, project responsibilities and time commitment:
Kate A. Schoenecker, Ecologist, USGS: project oversight, study design, data collection, data analysis, data interpretation, population modeling, publication (15%)
Sarah R.B. King, Research Scientist, CSU: study design, data collection, data analysis, data interpretation, publication (5% time)
Linda C. Zeigenfuss, Ecologist, USGS: data collection, habitat selection modeling, publication (15%)
Kate Searle, Ecological Modeler, CSU and CEH (Center for Ecology and Hydrology, Scotland, UK): data analysis, interpretation, population modeling, publication (10%)
Gus Warr, BLM WH&B State Lead: gather and radio marking, project oversight (5%)
Roger Oyler, BLM WH&B State Lead: water trapping and radio marking, project oversight (5%)
Mike Twedell, BLM WH&B Specialist: gather and radio marking, data interpretation, publication (10%)
Steve Bird, BLM WH&B Specialist: gather and radio marking, data interpretation, publication (10%)

C. RESEARCH PROPOSAL

BLM Wild Horse and Burro Program
Proposal for Collaborative Research Effort

1. Goals / Objectives / Hypotheses:

Goal:
The goal of our research is to conduct a descriptive study of the demographic parameters of two wild burro populations inhabiting different ecosystems to provide empirical data for population modeling, to improve management of wild burros, and to contribute to a better understanding of the ecology of the species.

Objectives:
1. To measure the basic demographic parameters of two wild burro populations; one in a Sonoran desert ecosystem in Arizona, and the other in Utah badlands. Parameters include fertility, fecundity, recruitment to age 1, age-class survival and mortality, habitat selection, movement ecology, and habitat range.
2. To quantify the behavior of female burros in order to provide better information about social dynamics and reproductive behavior of burros.
3. To build a state-space Bayesian model to predict environmental factors that have the greatest influence on burro demographic parameters; specifically aimed at determining environmental attributes that drive survival and population growth of wild burros.

Hypotheses:
This is a descriptive study. Descriptive studies describe how things are rather than setting-out to test hypotheses. As such, there are no experimental hypotheses.

2. Specific Aims:
Year 1 (Aug 2015-Sept 2016)
a) Visit study sites to make logistical preparations.
b) Between January and February 2016 conduct a gather to remove animals above Appropriate Management Level (AML) and place radio collars on 25-30 adult females (jennies) at Sinbad. Between March and April 2016 conduct water trapping at Lake Pleasant to deploy 25-30 radio collars on adult jennies.
c) Initiate the field test of radio collars, locating radio marked individuals ≥ 1x/month to check welfare of individuals wearing collars.
d) In winter 2015/2016 conduct aerial surveys to assess the size of the population before and after the gather at Sinbad, and after water trapping at Lake Pleasant.
e) In spring and summer 2016, monitor females with radio collars to check for foals. Monitor foals and radio marked adults through summer and the following fall/winter for survival.

Year 2 (Oct 2016-Sept 2017)
a) Continue the field test of radio collars, locating radio marked individuals ≥ 1x/month to check welfare of individuals wearing collars.

b) In fall 2016 collect fecal samples from radio marked females to determine pregnancy.
c) In winter 2016/2017 conduct an aerial survey to assess the size of both populations.
d) In spring and summer 2017, monitor females with radio collars for behavior and to check for foals. Monitor foals and radio marked adults through summer and the following fall/winter for survival.

Year 3 (Oct 2017-Sept 2018)
a) Continue the field test of radio collars and tags, locating radio marked individuals ≥ 1x/month to check individuals wearing collars.
b) In fall 2017 collect fecal samples from radio marked females to determine pregnancy.
c) In winter 2017/2018, or spring 2018 in Lake Pleasant, conduct aerial surveys to assess the size of both populations.
d) In spring and summer 2018, monitor females with radio collars for behavior and to check for foals. Monitor foals and radio marked adults through summer and the following fall/winter for survival.

Year 4 (Oct 2018-Sept 2019)
a) Continue the field test of radio collars and tags, locating radio marked individuals ≥ 1x/month to check individuals wearing collars.
b) In fall 2018 collect fecal samples from radio marked females to determine pregnancy. In winter 2018/2019 and potentially spring 2019 conduct aerial surveys to assess the size of both populations
c) In spring and summer 2019, monitor females with radio collars for behavior and to check for foals. Monitor foals and radio marked adults through summer and the following fall/winter for survival.

Year 5 (Oct 2019-Sept 2020)
a) Continue the field test of radio collars and tags, locating radio marked individuals ≥ 1x/month to check individuals wearing collars.
b) In fall 2019 collect fecal samples from radio marked females to determine pregnancy.
c) In winter 2019/2020 and spring 2020 conduct aerial surveys to assess the size of both population
d) In spring and summer 2020, monitor females with radio collars for behavior and to check for foals. Monitor foals and radio marked adults through summer and the following fall/winter for survival.
e) Initiate data analyses.
f) Conduct manuscript preparation.

3. Background and Significance/Preliminary Studies:

Wild burros are a remnant of the pioneer past of the American West, and are protected under the 1971 Wild Horse and Burro Act (Public Law 92-195). Burros have the potential for high population growth due to the low mortality and relatively high reproduction rates common to equids (Ransom et al. *In press*). Wild burros are found in the fragile desert ecosystems of the West, and may both directly impact the vegetation (Abella 2008) and compete with native sympatric ungulates for forage (Marshal et al. 2008, 2012). Burros are a domesticated variety of the African wild ass, so unlike the wild horse, they still have an extant progenitor (Jónsson et al. 2014) whereas the domestic horse and its nearest relative, the Przewalski's horse, only have a common ancestor (Lau et al. 2009). There is remarkably little published literature on the wild burro, with almost all research being conducted in the 1970s and 1980s. Compounding this problem is that there are almost no studies on the African wild ass due to its rarity and native range in the politically unstable and war-ravaged Horn of Africa (Moehlman et al. 1998). Management of burros has been impaired by this lack of knowledge, particularly because what little research has been done indicates that they are both socially and behaviorally very different from wild horses (Burden and Thiemann 2015), and have a different habitat use and diet (Schoenecker et al. *In press*). The National Academies of Science (NAS) recommended acquiring population ecology information on burros to better inform their management (National Research Council 2013).

Population Growth

Although there have been many aerial surveys conducted, surveying burros is fraught with challenges (Griffin 2015) and thus there are few reports of population growth rates in burro populations. Observational studies have been over a scale of months to a few years, or else based on sacrificed animals. In Australia, one population had a mean growth rate of 1.19 (Choquenot 1991); in America populations were estimated to grow by 20-25% annually (Woodward and Ohmart 1976, Norment and Douglas 1977). While it is likely that burros are affected by density dependent effects (e.g., Norment and Douglas 1977) this has only been examined in Australia where comparisons between a high density and low density population were made (Freeland and Choquenot 1990, Choquenot 1991). These studies showed that high density populations had lower growth rates, higher juvenile mortality and lower juvenile body condition compared to a population at low density. Furthermore at low density burros attained sexual maturity earlier, and the high density population was limited by density dependent mortality within the first six months of life. In America wild burro populations have been controlled by removals, which likely prevents them from reaching this ecological limit. The removals have often led to a female-biased sex ratio (Norment and Douglas 1977, White and Douglas 1980, Seegmiller and Ohmart 1981, Johnson et al. 1987), whereas in uncontrolled populations sex ratios tend to be at parity (Moehlman 1974, McCool et al. 1981, Hoffmann 1983, Choquenot 1991). Removals have also affected the age structure of some burro populations, skewing them towards younger age classes (Woodward 1979, Seegmiller and Ohmart 1981, Ruffner and Carothers 1982, Johnson et al. 1987) or preferentially removing young animals in other cases (Norment and Douglas 1977). These management activities affect the growth rate of burro populations.

Survival

There is little survival data on burros; mortality rates have only been reported in a few studies. In two graduate studies lasting four and three years respectively, few deaths or abortions were seen in one (McCort 1980), with no mortality of adults found in the other and only three known cases of abortion or post-partum death (Moehlman 1974). In another year-long study in Death Valley, only one mortality was documented, with no foal mortality found at all (Seegmiller and Ohmart 1981). However juvenile mortality is likely to be less visible than that of adults. Norment and Douglas (1977) reported over three times as many females thought to be pregnant as produced foals. They also observed fewer juveniles than foals, but could not determine whether this was due to mortality or emigration; they found only two dead foals and four adult burros dead from natural causes. Where survival has been modelled it has been shown to occur mostly in the younger age classes. In California, Perryman and Muchlinski (1987) calculated a 0.88 survival rate of 0 to 2 year olds, then varying between 0.96 and 0.52 per age class until 0% survival in the 7 to 9 year olds. In Australia highest mortality was seen in the first six months of life, but especially in the high density population, which also had a greater median age at adult death (Choquenot 1991).

Fecundity

Similar to other feral species (Grange et al. 2009), wild burros are fecund. Reproduction in burros can start as early as 18 months old (Woodward 1979, Johnson et al. 1987), with all females over two years old being reproductive (McCort 1980, McCool et al. 1981). The mean birth rate across studies has been reported as 0.68, with a range of 0.41-0.89 (Ransom et al. *In press*). In Australia fertility was high (64% to over 70% of females pregnant; McCool et al. 1981, Choquenot 1991), with similar rates seen in three populations in America: pregnancy rates were 62% to 89% based on autopsies ((Ruffner and Carothers 1982, Johnson et al. 1987), and 69% based on blood tests (Wolfe et al. 1989). It is common for a jenny (female burro) to give birth each year (McCool et al. 1981). Sixty percent of the pregnant jennies autopsied by Johnson et al. (1987) were also lactating, with 52% of known jennies in Death Valley giving birth in subsequent years (Moehlman 1974), although only 11% of the pregnant jennies tested by Wolfe et al. (1989) were lactating. Although fecundity is considered independent of density (Perryman and Muchlinski 1987, Choquenot 1991), the nutritional status of females is relevant to successful parturition and to provisioning young. Lower nutritional condition of jennies can result in higher juvenile mortality (Norment and Douglas 1977, Choquenot 1991), and is shown in other ungulate species to determine survival of neonates (Thorne et al. 1976). Despite this, in a population where most burros foaled every year they remained in good condition, while sympatric cattle were in such poor condition they had to be euthanized on humane grounds (McCool et al. 1981). Marking individuals helps refine foaling estimates: in Death Valley nine out of ten marked females foaled (Norment and Douglas 1977), and in Arizona all 13 marked jennies had foals (Seegmiller and Ohmart 1981). With markings on individual jennies, coupled with fecal sampling to measure pregnancy rates, a thorough assessment of fertility and fecundity of wild burros can be achieved.

Reproductive Ecology

Burros have a 12 month gestation period (365-370 days; Grinder et al. 2006) and like other equids are polyestrous (Henry et al. 1998). In less seasonal environments, such as Sri Lanka and an island off the coast of Georgia (USA) they have been observed to show estrus behavior and produce foals in every month of the year (McCort 1980, Santiapillai et al. 1999). Reproductive seasonality has been shown in captive conditions, and how pronounced it is, is likely related to climate (Ginther et al. 1987, Henry et al. 1998). In wild populations inhabiting arid environments there are conflicting accounts of the season of natality. In Australia it was reported as seasonal, but not related to the rainfall pattern in one study (McCool et al. 1981) and synchronized with the annual flush of quality forage in another (Choquenot 1991). In America one study could not determine a foaling season (Seegmiller and Ohmart 1981), and another reported births limited to March through July, with one exception (based on 20 aged embryos; Ruffner and Carothers 1982). In Death Valley there was a peak in natality in the hottest months (May to July), with foals seen in October (Moehlman 1974, Norment and Douglas 1977). Variability in breeding season means that there is the potential for some females to be in estrus throughout the warmer months, which can result in females being continually harassed by males unless they are pregnant (Moehlman 1974). This may explain the high pregnancy rates seen, and may account for why burros exhibit a different social system compared to wild horses.

African wild asses have a territorial social system called "resource defense polygyny" (Klingel 1998). In this system there are no permanent affiliations or associations between adults, only between a female and her offspring (Klingel 1998, Moehlman 1998*a*). This has been observed in most wild burro populations, especially in arid environments, with the smallest unit of social organization being a jenny and foal (Woodward 1979, Seegmiller and Ohmart 1981, Hoffmann 1983, Moehlman 1998*a*). However other types of social group have been seen as well: family groups with at least one adult of each sex plus offspring (similar to a horse harem group), all female groups with offspring, all male groups of all ages, and a solitary post-reproductive female (Ruffner and Carothers 1982, Jenks et al. 1996). There are also differing accounts of how strongly territoriality is expressed by jacks (male burros), with one study reporting territoriality even in a pasture (Henry et al. 1998), and others observing no territoriality whatsoever (Hoffmann 1983). It is possible that territories are expressed in this species, but that it requires detailed observations to identify them (Woodward 1979). Territories are thought to be an adaptation to arid environments where food and water are sparsely distributed, resulting in high competition among females for resources (Rubenstein 2010). Lactating females need to remain close to water, but non-lactating females can move further to different food patches, and both classes of female will come into estrus and be sought by males. As males cannot maintain both female classes when resources are spread widely they establish territories around resources like water holes (Rubenstein 2010). Territories shelter females from male harassment, because only the dominant male who holds the territory can mate with them (Woodward 1979, Moehlman 1998*a*), whereas outside a territory an estrous female may attract up to 18 males, who will compete for her and mate often (Woodward 1979, Moehlman 1998*b*). Territoriality has been well studied in Grevy's zebra (Sundaresan et al. 2007). It is important to study this further in wild burros as it has ramifications for female habitat use if they are avoiding males, and male habitat use if they are clustered near water sources in order to intercept females. Understanding the reproductive and social system of burros is vital for population control management, such as the use of contraceptives. We propose that a solid understanding of the reproductive and behavioral ecology of wild burros is necessary before applying widespread management activities to achieve a population growth reduction outcome.

Habitat Interactions and Movements
Burro diet has been examined in much greater detail than their demography. Like other equids they can survive on forage with greater bulk and lower nutrition than ruminants, which allows them to survive in arid regions where there is sparse food for livestock (Schoenecker et al. *In press*). Burros preferentially eat graminoids and forbs over shrubs (Jordan and Colton 1979, Potter and Hansen 1979, Abella 2008), but in some areas and during winter browse makes up a large portion of their diet (Schoenecker et al. *In press*). Burros are generally found within 5 or 6 miles of water, staying closer in summer than winter (McKnight 1958, Norment and Douglas 1977, Seegmiller and Ohmart 1981, Moehlman 1998*a*). Like other wild ass species, wild burros have been reported to dig their own water holes in washes (McKnight 1958, Seegmiller and Ohmart 1981, S. King pers. obs.). Data on wild burro habitat use and home ranges is sparse. A few studies report home range sizes: in Death Valley female home ranges were 1.3 to 18.6 km^2, male home ranges were 2.3 to 40.6 km^2 (Moehlman 1998a), mean home range was 68.1 km^2 with no difference between males and females in Norment and Douglas (1977), home range was 4 km^2 in summer and up to 10 km^2 in winter (White and Douglas 1980), and the largest range was 60 km^2 (Seegmiller and Ohmart 1981). In the Chemehuevi Mountains home range was reported as 4 to 97 km^2 (mean = 32 km^2; Woodward 1979). None of these data were gathered using Geographic Positioning Systems (GPS) technology nor analyzed with Geographic Information Systems (GIS), as these technologies were in their infancy at the time of the studies. The home ranges given are therefore relatively crude Minimum Convex Polygons, and also vary from study to study depending on intensity of observations. However they do agree that home ranges tend to be smaller in summer than winter, because wild burros are released from water stress in winter (Norment and Douglas 1977, Moehlman 1998*a*). In Death Valley burros were reported to be migratory, covering large areas in seasonal movements (Moehlman 1974, Norment and Douglas 1977, White and Douglas 1980): individuals marked with VHF collars moved over 452 km (Norment and Douglas 1977).

General Ecology
This background represents the fruits of a thorough literature search, highlighting how little is known about wild burro ecology despite our long association with them as a domesticated species. The lack of demographic information on burros has hindered effective management of their populations (Johnson et al. 1987), and understanding the social reproductive system of this species is essential for appropriate and targeted use of contraception. Population models based on demographic data will enable estimates of the number of animals that need to be treated or removed and to conduct science-based management of the species (National Research Council 2013).

4. Experimental Approach:
The two HMAs that are part of this study will not be gathered for the duration of the study period. Empirical data gained from these HMAs will be used for population

modeling, to improve management of wild burros, and to contribute to a better understanding of the ecology of the species.

Radio Collar Deployment

As part of a previously funded and approved proposal ("Developing and testing aerial survey techniques for wild burros"), we will deploy radio-collars on 25-30 burro jennies across each of the two HMAs (n= 50-60 collars total). Radio collars have long signal transmission ranges and battery lives (3-5 years), and have been used on burros in the USA (Seegmiller and Ohmart 1981) and Western Australia (Woolnough et al. 2012, M. Elliott, Dept. of Agriculture and Food Western Australia, pers. comm.). Radio collars will remain on burros for up to 4.5 years, at which time they will be scheduled to fall off with a timed release mechanism. USGS is conducting a separate study to test radio collar safety on captive burros, starting in February 2015. Collars survive wear and tear longer on females (jennies) than on males (jacks) (Norment 2012). The effort and time required to capture and mark 25-30 burros in each of the two study populations could be substantial. We will rely on BLM staff for wild burro capture and handling operations following approved BLM gather, trapping, and handling protocols (IM 2013-059, BLM et al., 2015). USGS or other experienced personnel will be on hand to conduct radio collar fitting.

We will order radio collars to be made with frequencies that have no interference at study sites: we will request to use VHF and GPS wildlife radio frequencies that will not conflict with other agencies or tribes. Before ordering radio collars for each HMA, we will use ground-based and aerial telemetry to confirm that there is no signal interference on the frequencies for the area.

During the gather or water trapping we will fit jennies with Global Positioning System (GPS) and/or Very High Frequency (VHF) radio collars. Individuals to be radio marked will be randomly selected during the gather or water trapping by placing radio collars on every 3rd or 4th or 5th jenny in the line-up until all collars are deployed assuming the individual is an adult in good health and body condition. If not, the next individual jenny will be selected. Collars will be placed on up to 30 adult females ($\geq$3 years old based on tooth wear estimation) that have a Henneke body condition score of 4 or greater (i.e., "moderately thin" and fatter; Henneke et al. 1983), stratified by adult age class (3-5, 6-9, >10 years old). Animals that are "thin" (Henneke score of $\leq$3), deformed, or who have any apparent neck problems will not be fitted with a collar. All personnel involved in handling animals will have previously completed the BLM's Comprehensive Animal Welfare Program (CAWP) training. For fitting radio collars, burros will be brought through a chute or possibly a squeeze chute, have a few hairs plucked for genetic analyses, and be given a freeze mark on the neck with a unique BLM identifier using the International Alpha Angle System, with the last four digits of this identifier freeze-marked on their left croup (conducted as part of BLM policy).

The design and vendor of collar used will be based on the results of the ongoing USGS radio collar and tag study at the BLM Pauls Valley adoption facility in Oklahoma. Placing radio collars on wild burro jennies at Sinbad and Lake Pleasant HMAs will constitute our first field test of radio collars in wild as opposed to captive conditions. To ensure that there are no impacts on animal welfare, all individuals wearing a collar will be visually observed at least once a month during winter (September to Feb), and at least every two weeks during summer (March to August).

At each site 10 of the radio marks will be GPS and the other 15-20 will be simple VHF radio transmitters. Collars with GPS will be set to collect a location every 20 minutes for home range and habitat analyses during the summer and potentially less intensively during the rest of the year to preserve battery life. VHF collars or tags will be used to locate marked individuals throughout the year to record births and deaths in both HMAs, and behavior at Sinbad HMA. All radio collars will have a manual release mechanism in case of emergency, and a timed release which will be programmed to release at the end of the study.

Field Monitoring
We will conduct ground monitoring of radio collared females at least every other week during summer (March-August) and at least 1x/month in winter (Sept-Feb) to check collars, check for foals, and obtain survival and location data during each year of the study period. We will collect fecal samples from marked females in late autumn each year to determine pregnancy status, and locate them in March-August to ascertain foaling success. We will document the sex ratio of new foals by sexing individuals visually, using binoculars or a scope if needed. Because we are not able to radio track and individually identify males (other than the routine freeze mark applied by BLM), we are not able to determine survival, habitat selection, and movements of males. However we will collect some behavior data on males at Sinbad, when they are associated with marked jennies.

Behavioral observations (Sinbad HMA only)
Behavioral observations will be conducted in the Sinbad population during the breeding season, in order to document reproductive behavior. Breeding season in burros is unclear from the literature, but we expect it to be when the vegetation is greenest in this seasonal ecosystem, therefore we will intensively observe burros between March and July. Observations will begin in the first March after jennies are fitted with radio collars, and will continue each year of the study. No behavioral observations will be conducted in Lake Pleasant HMA, Arizona. Individuals will not be given names, but will be referred to by the last four digits of their unique BLM numeric identifier.

Behavioral observations will focus on 20 radio collared burro jennies selected randomly from across age classes. Burros are expected to have no permanent social associations beyond a jenny and her offspring (Moehlman 1998), but behavior of all members of a group associating with a focal animal will be recorded, plus the behavior of any males within 200m (after Sundaresan et al. 2007). This means that sample sizes of data collection will be larger than the 20 focal animals, as well as providing information on social networks within the population. Due to the logistics of travel around Sinbad HMA we will stratify the area for observations, and then randomize focal animals within these stratifications, ensuring that all focal animals are observed evenly but randomly. Every 10 minutes during a 4 to 6 hour observation session the basic state of each individual (i.e., feeding, standing, moving) within a social group and the identity of their nearest neighbor will be recorded. All-occurrence sampling (Altmann 1974) will be used to record individuals involved in incidents of agonistic behavior (e.g., bites and bite threats, kicks and kick threats), affiliative behavior (e.g., allogrooming), and reproductive behavior (e.g., estrus behavior, mating and mating attempts, and scent marking behavior); detailed data will be taken at each event.

Burros spend over half their time foraging (Canacoo and Avornyo 1998, Lamoot et al. 2005) and we expect social interactions to be rare, therefore many hours of observations are required in order to provide enough data for meaningful statistical analyses. With a crew of four field technicians we aim to gather 1600 to 1800 hours of observations per field season, which will be sufficient for statistical analyses. To gather data at a greater intensity or on more individuals would require a larger workforce, and our sample sizes are comparable to other studies. In the 1970s up to 7 VHF radio collars and up to 32 color-marked collars were deployed in three different burro populations (Norment and Douglas 1977, Walters 1979, Seegmiller and Ohmart 1981). In more recent equid studies up to 19 radio collars were used to examine the ecology of Asiatic wild asses (Kaczensky et al. 2011), although not all simultaneously, with other equid studies only having collars on four to ten individuals (Goodloe et al. 2000, Fischhoff et al. 2007, Girard et al. 2013, Owen-Smith and Goodall 2014). Behavioral studies of wild burros are rare: population wide studies with low individual intensity were conducted by Moehlman (1974, 1998) on 237 individuals in Death Valley, McCort (1980) on 75 individuals on Ossabaw Island, Georgia, and Rudman (1998) on 76 on the island of St. John, with animals being observed as they were encountered. Canacoo and Avornyo (1998) and Lamoot et al. (2005) conducted more intensive studies, but on only 3 and 12 adults respectively.

Behavioral analyses from Sinbad will follow the analytical methodology of Ransom et al. (2010) and King (2002). Observations of each focal burro will be expressed as frequency of behavior (count/total hours observed per year). By weighting frequency of behavior per observational hour, unforeseen difficulties in obtaining an equal number of observations per individual will not negatively affect the model. We will model behavior as a function of age, group size, time of day, month, and sex.

5. Statistical Methods:

Population Growth

As part of a previously approved study ("Developing and testing aerial survey techniques for wild burros"), we will conduct annual aerial surveys for population size, which will be analyzed using approved analytical procedures for all BLM surveys (simultaneous double observer; Griffin et al. 2013). Using these annual population surveys, population growth rates can be calculated following Garrott and Taylor (1990) in which annual population growth (of individuals ≥1 year old) can be calculated using the equation $\lambda_t = N_t / (N_{t-1})$, where λ_t is the growth multiplier from year $t - 1$ to year t, and N is the population size. Lambda (λ) represents the apparent growth rate of the population.

Fertility

Pregnancy rates will be determined by fecal estradiol (following D. Baker (CSU; pers. commun.) which has been shown to be a more reliable indicator of pregnancy status than fecal progesterone. We will follow methods established for equids in Asa et al. (2001).

Fecundity

We will determine foaling rates from aerial surveys and direct observations of radio marked jennies, assuming that foals of collared jennies will be reliably detected at the same time as their mothers.

Sex Ratios
We will record sex ratios of new foals born each year, and calculate the average sex ratio for each HMA over the 4-5 years, as well as the range of sex ratios in each HMA; and conduct Chi-square tests to determine if sex ratios are significantly different ($P < 0.05$) from parity following Garrott (1991).

Recruitment
We will record survival of foals of $n = 50$ radio marked mares to age 1, and calculate average recruitment over 4-5 years per HMA, assuming that yearlings of collared jennies will be reliably detected at the same time as their mothers, or that we can reliably identify them by pelage markings.

Survival
We will record age-specific survival based on observations of radio collared individual jennies collected during the breeding and foaling season (March – Aug) and during winter (Sept-Feb). We aim to assess survival of adults females, yearlings, and foals on a seasonal basis.

Habitat Interactions
Spatial location data from radio collared individuals in both HMAs will be analyzed in ArcGIS following methods similar to King and Gurnell (2005). We will use cluster analyses to examine movement patterns and distance over time to measure movement rates. We will plot wild burro group locations to determine distribution and calculate home range and amount of overlap in home range for each GPS radio marked individual using 90% and 95% kernel density estimates (Silverman 1986).

To model seasonal and annual resource selection by wild burro jennies, we will use GPS location data from collared individuals, a vegetation classification of the area, and resource selection function (RSF) methods following Manly et al. (2002). We will fit seasonal RSFs of the form:

$$w(\boldsymbol{x}) = \exp(\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_8 x_8),$$

where $w(\boldsymbol{x})$ is the RSF, β_1 the selection coefficient for habitat type 1 and x_1 the observed proportion of vegetation type 1 within 50 meters of a wild burro group location or random location. We will use logistic regression to estimate RSF coefficients of this exponential model for each of the 4 seasons. We will use the same random 'available' locations for all seasons to ensure that differences in habitat selection coefficients among seasons are due to changes in habitat use rather than changes in the definition of habitat availability. We assume habitat availability to be constant for all seasons within the HMA. We will map relative selection values using ArcGIS 9.2 (ESRI, Redlands, CA) for each season.

Bayesian State-Space Modeling

The benefit of using a state-space modeling framework is that we can utilize multiple sources of data to inform inference, combining new intensively collected data (this project) with previous data collected by BLM dating back 35 years to support a more robust model. Of particular importance for large mammal studies, state-space modeling enables the separation of observation error and process variance in time-series models, allowing for more realistic parameter estimates and future predictions for population trends (Clark 2003; Freckleton *et al.* 2006). Both process variance and observation error typically influence population time-series data for large herbivores. Process variance is uncertainty that arises because population dynamics are not entirely deterministic across space and time, while observation error is uncertainty derived from our inability to exactly capture the number of animals in each age and sex class at any point in time. State-space models have two main components; a process model and a data model. The data model describes the relationship between the observed data and the true state by incorporating observation error. The dynamics of the true state of the population through time are described by the process model, which explicitly incorporates process variance. Observations of time-series data (e.g., census estimates of total population size) are assumed to arise from some 'true' unobserved state that represents the true dynamics of the population (Calder *et al.* 2003).

State-space modeling is ideally suited for situations where there is uncertainty about the processes that affect population dynamics, and when observations of population size contain error. The use of a hierarchical model structure allows for the organization of individuals comprising the population in ways that permit inter-individual variation in vital rates, such as survival and recruitment. By explicitly incorporating variability associated with space, time and individual variation, more realistic parameter estimates and future predictions for population trends can be made (Clark 2003a). A failure to separate observation error from process variance can lead to erroneous conclusions, such as the detection of strongly density-dependent dynamics when in fact density dependence may be weak or even absent (Freckleton et al. 2006). Hierarchical Bayesian methods (e.g., state-space models) can provide direct links between deterministic population models (for instance describing age and sex classes, recruitment, survival and density-dependent effects) and the noisy and often limited data available for model parameterization and evaluation (Clark 2003b). They provide a coherent and consistent framework for breaking down complex problems into computable sub-models (Biggs et al. 2009).

Data

We will use age class, and sex data obtained at the initial gather and throughout the study from ground observations of 25 radio collared jennies (and their foals), and the number of wild burros in the population obtained during annual aerial surveys from 2016 through 2020. Age will be determined by tooth eruption (Hadrill 2002) at the gather when individual jennies will be radio marked. Prior to 2016, we will use inventory records from BLM, which provide data on number of adults and foals during roundups, and minimum counts and corrected population estimates from aerial surveys. We will incorporate precipitation and snow in the model (as a proxy for vegetation production); climate input data will be obtained from the National Climatic Data Center (*http://www.ncdc.noaa.gov/oa/ncdc.html*).

The Model

We will develop a discrete time, stage-structured model to describe the dynamics of four age and sex classes of wild burros: female foals (class 1); male foals (class 2); females ≥1 yr (class 3); and males ≥ 1 yr (class 4; Figure 1). We will also have total population size from aerial surveys, classified to adults and foals. If there are sufficient data to further refine age classes (for example, if yearlings are reliably identified by body size and we can locate them with collared jennies), we will further segregate age class. Some of this will depend on the quality and reliability of the data; that is, we know we can obtain data on the jennies, but we don't know how reliably we will find jacks. Jacks will have a unique freeze brand to identify individuals, but they will not have a radio signal to locate them reliably.

The process model

The process model describes the evolution of counts $N_{i,j}$ over time as a function of recruitment and survival rates. Recruitment is defined as the number of foals produced per jenny that survives to 1 year. Survival is defined as the proportion of each age and sex class that survives to the next year. We will record a sub-sample of population level survivorship from age 0 to 1 year (N_1 to N_3; N_2 to N_4) by locating 25 radio collared jennies and their mixed gender foals with ground tracking. The general framework of our population model considers 4 age and sex classes, but specific data for these 4 categories of animals will only be available for the last 5 years of the project (this study). To fully exploit all available data (~1980 – 2020) we will adapt the formulation of the state space model such that in different time periods different data sources are used to inform parameter estimates (e.g., minimum counts, age-sex specific counts during gathers, individual-level observations).

The general structure of the model is as follows:

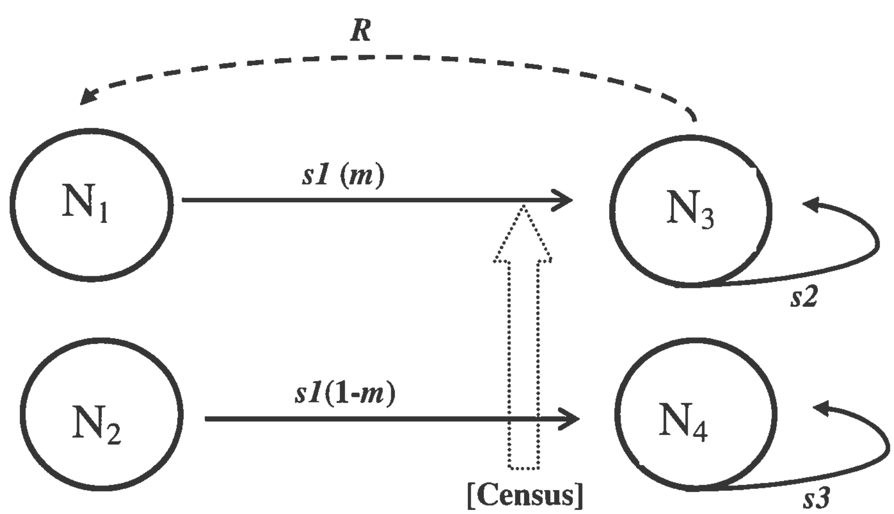

Figure 1. Diagram of state-space population model for wild burros depicting 4 age and sex classes, where N_1 is the population size of female foals, N_2 is male foals, N_3 is jennies > 1 year, and N_4 is males > 1 year; *s* is the survival rate from one age class to the next; *m* is the proportion of offspring that are female; and R is the recruitment to age 1 year.

The Data Models

Because our model will include two different sources of data collected over contiguous time intervals we specify two data models to fully account for temporal variation in the extent of observation error.

The data models describe the relationship between the observed data, Y_{it}, (the number of animals of the *i-th* age-sex class in the *t-th* year) counted during census) and the underlying 'true' state of the population N_{it} (the total number of animals in the population including those animals that were not included in the count) by explicitly incorporating observation error. The relative population size within each of the six age/sex classes in year *t* is modeled using a multinomial distribution,

$$(Y_{1t}, Y_{2t}, Y_{3t}, Y_{4t}) \sim \text{multinomial}\left(\frac{N_{i,t}}{N_{\text{total},t}}, Y_{\text{total},t}\right)$$

and the total population size is modelled using a Poisson-gamma mixture

$$Y_{total,t} \sim \text{Poisson}(\lambda_t) \text{ and } \lambda_t \sim \text{gamma}\left(\frac{N^2_{total,t}}{\sigma^2_o}, \frac{N_{total,t}}{\sigma^2_o}\right),$$

where $N_{total,t} = \sum_{i=1}^{4} N_{i,t}$ and $Y_{total,t} = \sum_{i=1}^{4} Y_{i,t}$ denote, respectively, the true total herd size and the observed count of total herd size. This Poisson-gamma model is more flexible than a standard Poisson model because it allows for the possibility that the variance of the Poisson distribution is not equal to the mean, and because it allows the variance to change over time. σ_o represents the magnitude of observation error (standard deviation) associated with the counts of total herd size, and is treated as an unknown parameter to be estimated during model fitting.

During ~1980 to 2015 we have counts on the number of foals and adults in the population approximately every 4 years (BLM burro minimum counts). During this time period we will use a binomial distribution to estimate for the number of foals and adults in the population at time *t*:

$$y.n_{i=1,t} \sim \text{binomial}(p_t, \sum_{i=1}^{2} y.n_{i,t}),$$

Where $y.n_{i=1,t}$ is the number of foals in the population at time *t*, $y.n_{i=2,t}$ is the number of adults in the population at time *t*,and p_t is the model's estimate of the proportion of the population made up of foals at time *t*.

From 2016 to 2020 we will obtain more detailed population estimates, age and sex classes, and will use a multinomial distribution with age-sex classes to estimate the number of animals in each age/sex class at time t:

$$y._{n_{i,t}} \sim \text{multinomial}(p_{i,t}, \sum_{i=1}^{4} y._{n_{i,t}}),$$

Where $y._{n_{i,t}}$ is the number of animals in age/sex class i in the population at time t, and $p_{i,t}$ is the model's estimate of the proportion of sex/age class i at time t.

Our model will be defined with a four element column vector $\mathbf{N}_{i,t} = [(N_{1,t},, N_{2,t}, N_{3,t}, N_{4,t})]^T$ that includes the number of animals in each age class at time t, indexed by i = 1: female foals, i = 2: male females, i = 3: jennies > 1 year, i = 4: jacks > 1 year. Thus, $N_{1,t}$ would be the number of female foals at time t.

The estimate of total population size at time t is given by $N_{total,t} = \sum_{i=1}^{4} N_{i,t}$

We will estimate three survival rates:

$s1$: the probability of survival of foals to age 1,
$s2$: the probability of survival of 1-year old females to age 2 and onwards,
$s3$: the probability of survival of 1-year old males to age 2 and onwards.

From ~1980 to 2015, survival rates are stochastic and are estimated solely from repeated counts of adults and foals each interval:

$$s_i \sim uniform(0,1)$$

However, from 2016 to 2020 individual level data on the survival of foals, and 1+ year olds will be collected for a subset of the total population, which will be used to inform overall estimates of age and sex specific survival during this time interval. The model during this time interval will be formulated such that Binomial data models estimate the probability of survival for each age class (foals, 1+ year old females, 1+ year old males):

$$surv_i \sim \text{Binomial}(p_i, N_i)$$

Where *surv* i=1 is the number of foals surviving to age 1, i=2 is the number of 1+ year old females surviving to age 2 and onwards, i=3 is the number of 1+ year old males surviving to age 2 and onwards. N_i are the total number of animals in each age and sex class. These survival estimates for the population sample will then inform overall estimates for age-specific survival for the entire population:

$$\text{logit}(p_i) \sim Normal(s_i, \varepsilon_i)$$
$$\varepsilon_i \sim Normal(0, tau.\varepsilon_i)$$
$$tau.\varepsilon_i \sim gamma(0.01, 0.01)$$

where the stochastic estimates for s_i are used within the equations specifying the matrix population model below, and ε_i is the residual error associated with the survival estimates because not all animals in the population have individual-level survival data.

A set of possible candidate models will be considered for the effects of population density and climate variables upon the recruitment rate, R_t, assuming that the logit-transformed recruitment rate is a linear function of the explanatory variable(s). The model assumes that recruitment rate is related to X_t:

$$\log\left(\frac{R_t}{1-R_t}\right) = b_0 + b_1 X_t$$

where X_t is a measure of e.g., population density, weather, etc. We will consider models that relate recruitment to one or more of: total population size ($N_{total,t}$), mean minimum winter temperature, maximum summer precipitation, and other environmental variables.

We will include a density-dependent effect of total population size on recruitment that assumes recruitment is an inverse logit function of the total population size, i.e.,

$$R_t = \frac{e^{b0+b1 \cdot N_t}}{1+e^{b0+b1 \cdot N_t}}.$$

We assume that the true population size for the ith age/sex class at time t can be represented as a lognormal distribution with median $\mu_{i,t}$ and standard deviation σ_i, where σ_i represents the process standard deviation on the log scale for age/sex class i (i.e., the process variance). We define m as the proportion of offspring that are female. The resulting population dynamics process model is given by:

$$N_{i,t+1} \sim \text{lognormal}(\mu_{i,t+1}, \sigma_{pi})$$

for i = 1,…,4, where

$$\mu_{1,t+1} = s_3 \cdot N_{3,t} \cdot R_t \cdot m$$
$$\mu_{2,t+1} = s_3 \cdot N_{3,t} \cdot R_t \cdot (1\text{-}m)$$
$$\mu_{3,t+1} = (s_1 \cdot N_{1,t}) + (s_2 \cdot N_{3,t})$$
$$\mu_{4,t+1} = (s_1 \cdot N_{2,t}) + (s_3 \cdot N_{4,t})$$

We use a lognormal distribution because it is appropriate for data that are continuously distributed with positive values only, where the logs are normally distributed.

Thus the actual (unknown) population sizes in year t + 1 are assumed to follow:

$N_{1,t+1} \sim \text{Lognormal}(\mu_{1,t+1}, \sigma_1)$
$N_{2,t+1} \sim \text{Lognormal}(\mu_{2,t+1}, \sigma_2)$
$N_{3,t+1} \sim \text{Lognormal}(\mu_{3,t+1}, \sigma_3)$
$N_{4,t+1} \sim \text{Lognormal}(\mu_{4,t+1}, \sigma_4)$

The Hierarchical State-Space Model

Let $\boldsymbol{\theta}$ be a vector of the parameters in the process model, excluding process variance. Let σ be the vector of process standard deviations for process variance, such that $\sigma = (\sigma_1, \sigma_2, \sigma_3, \sigma_4)$. Let η be a vector containing the estimates of the initial conditions for each age/sex class. Given the assumptions on the distributions above, the fully stochastic, Bayesian model is specified by:

$$p(\theta, \sigma_{pi}, \sigma_o^2, \mathrm{N} \mid y_{\cdot n_t}) \propto \prod_{t=2}^{n} \prod_{i=1}^{4} \text{lognormal}(\log(N_{i,t} \mid \mu_{i,t}), \sigma_{pi}) \times$$

$$\prod_{t=1980}^{2020} \text{Poisson}(y_{total,t} \mid \lambda_t)\ \text{gamma}\left(\lambda_t \mid \frac{\left(\sum_{i=1}^{4} N_{i,t}\right)^2}{\sigma_o^2}, \frac{\left(\sum_{i=1}^{4} N_{i,t}\right)}{\sigma_o^2} \right) \times$$

$$\prod_{t=1980}^{2015} \text{binomial}(y_{\cdot n_{i=1,t}} \mid p_t, \sum_{i-1}^{2} y_{\cdot n_{i,t}}) \times$$

$$\prod_{t=2016}^{2020} \text{multinomial}(y_{\cdot n_{i,t}} \mid p_{i,t}, \sum_{i-1}^{4} y_{\cdot n_{i,t}}) \times$$

$$p(\theta)\, p(\sigma_{pi})\, p(\sigma_o^2)$$

We will adopt a fully Bayesian approach to statistical inference within the population model. This involves assigning prior distributions to the initial population estimates for each of the four classes, and to each of the unknown parameters within the model: the magnitude of observation error in the count of total herd size (σ_o), the level of process variability within the population size each class ($\sigma_{p1}, \ldots, \sigma_{p4}$), the survival probabilities ($s_1, \ldots, s_3$), the proportion of female births m, and the intercept (b_0) and regression coefficient(s) (b_1, and possibly $b_2 \ldots$ etc.) associated with the effects of explanatory variables upon recruitment. All prior distributions will be chosen to be conjugate whenever possible, and will be taken to be diffuse (as uninformative as possible). Very little data exist for wild burro populations, however prior distributions (e.g., for survival parameters) will be made appropriately informative where data exist.

Model implementation

Bayesian inference involves drawing inferences about the joint posterior distribution of the unknown quantities within the model (the model parameters, the true number of individuals in each age/sex class in each year, and the initial population counts), conditional upon the data (the observed count for the number of individuals in each class in each year). We will generate simulations from this posterior distribution using Markov chain Monte Carlo (MCMC) methods implemented in WinBUGS (Lunn *et al.* 2000) and R (R-Development_Core_Team 2009).

We will simulate a dataset using known distributions, processes, and parameter values and use this dataset to assure estimation procedures are accurate. We will use the population data to estimate the posterior distribution for each parameter using MCMC methods implemented in WinBUGS (Lunn et al. 2000) or JAGS (Plummer 2003) and R (R-Development_Core_Team 2009). MCMC chains will be initialized with 3 different sets of starting parameter values. We estimate that after discarding the first 200,000 iterations, 30,000-50,000 samples will be accumulated from each chain, however the exact length of chain burn-in and subsequent samples will be determined by model convergence assessments. Convergence will be assured by visual inspection of trace plots and Raftery diagnostics (Raftery and Lewis 1992, 1995) to assure stationarity and that plots are non-directional. We will use diagnostics of Gelman (Brooks and Gelman 1998) and Heidelberger (Heidelberger and Welch 1981, 1983; Schruben 1982) implemented in the coda package (Plummer et al. 2010) in R.

6. Pitfalls and Limitations:

Use of radio collars in this study will save a great deal of time locating marked jennies to check for foals, etc. and allow for 24-hour recording of movements and habitat use. However, a potential limitation to the use of radio collars is technological failure. GPS locations are dependent on the unit functioning correctly and the antenna having a clear view of the sky. We have tried to supplement the radio marked sample in in our study to account for some attrition. No problems have been observed among collared jennies in the Pauls Valley radio collar trial. However, while every effort is being made to develop a collar that is safe and comfortable, and experienced personnel will fit them on wild burro jennies as part of this study, we cannot rule out the possibility of a catastrophe or mortality of a burro jenny wearing a collar as part of the field test of radio collars.

Bayesian modeling is the most robust approach to gain reliable information about population growth rates and other population attributes. Five years of data – even the individual-level data that we will collect-- will not be adequate to build a population model using a classical frequentist approach. However, within the Bayesian framework we can exploit data collected by BLM from ~1980 to 2015 to supplement the data we collect from 2016-2020. From our discussions with WH&B Specialists, we feel the amount of pre-existing data is sufficient, coupled with the individual level data from this study, to build a robust population model for wild burros.

7. Anticipated effects:

Gathers

Gathers and water trapping will be conducted by the BLM following their established guidelines and policy (BLM et al., 2015, BLM IM 2013-059). We anticipate that gathers and water trapping will be carried out calmly and at as slow a speed as possible in order to minimize stress and injury, however it is possible that small injuries (at the level of abrasions) may occur. Due to the removal of animals after the preliminary gather to bring the population to AML, and because animals will have to travel back to their home ranges or territories after the gather, individuals may not return to the same social group in which they were found before the gather, although the frequency of this is not known.

Collars and tags

Based on numerous other studies that have used GPS or VHF radio collars to study the ecology of wild ungulates and equids in particular, we expect these devices to have minimal effects on the animals wearing them. However the following effects are possible:

1. Collar going over the ear: In other equids this has only been observed to happen in males (G. Collins, USFWS and P. Kaczensky Vetmeduni Vienna, personal communication), which will therefore be fitted with tags rather than collars in this study. All animals wearing collars and tags will be observed at least once a month throughout the year. Should the collar go over the ear of a jenny the remote-release (also known as the drop-off mechanism) can be deployed remotely (by radio-tracking the individual and walking to within 200m of it). If this fails the collar will be removed after capturing the animal with bait or water traps or darting, depending on what options are best in the specific situation and HMA.
2. Neck abrasion/sores: Rubbing and sores have not been reported in other studies where female equids have been collared (e.g., Collins et al. 2014), and were not seen in burro jennies during the first 6 months of our collar test at Pauls Valley adoption facility, Oklahoma. We therefore do not anticipate that they will be a problem. All burro jennies will be visually checked at least monthly, and this check will include for rubbing or sores. Burros in the wild are susceptible to wounds, most of which heal naturally. If sores caused by a collar have not healed within 4-5 weeks of when it was sighted, that individual will have its collar remotely triggered to drop off, or will be captured with bait or water traps or darting, depending on what options are best in the specific situation and HMA.
3. Collar too tight: Every effort will be made to put collars on at the correct tightness, which in burros means comfortable with 2 fingers vertically under the collar so it can move a little. Should an individual put on an unusually large amount of weight it is possible that the collar may become too tight. In this case the individual will be bait-trapped and the collar removed or replaced, or we can remotely remove the collar with the manual drop off mechanism.
4. No problems have been observed among collared burro jennies in the Pauls Valley trial and every effort is being made to develop a collar that is safe and

comfortable. However, despite that experienced personnel will be fitting the collars on jennies, we cannot rule out the possibility of a catastrophe or mortality of a horse wearing a collar as part of the field test of radio collars. We cannot completely prevent an accident, although collars will all be equipped with a manual release mechanism so managers or researchers can remove the collar if needed.

Aerial surveys
Flying population estimation surveys is part of the routine management for wild burros, but they are not typically conducted every year. Flying over burros can cause stress to individuals, where they can run and use energy resources in their flight response from the helicopter.

Other
We anticipate some mortality and injuries to individuals due to the rigors of life in the wild, and specifically expect mortality of juveniles in early spring. These are natural processes. Quantifying survival (and therefore mortality events) is one of the aims of our study.

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Schoenecker, K.A, S. R. B. King, M. Nordquist, N. Dejid, and Q. Cao. In press. Habitat and diet of equids. Chapter 4 *in* J. I. Ransom and P. Kaczensky, editors. Wild Equids Ecology, Management, and Conservation. Johns Hopkins University Press.

Seegmiller, R. F., and R. Ohmart. 1981. Ecological relationships of feral burros and desert bighorn sheep. Wildlife Monographs 78:3–58.

Sundaresan, S. R., I. R. Fischhoff, and D. I. Rubenstein. 2007. Male harassment influences female movements and associations in Grevy's zebra (*Equus grevyi*). Behavioral Ecology 18:860–865.

Thorne, E.T., R.E. Dean, and W.G. Hepworth. 1976. Nutrition during gestation in relation to successful reproduction in elk. Journal of Wildlife Management 40:330-335.

White, L. D., and C. L. Douglas. 1980. Population demographics of feral asses in Butte Valley, Death Valley National Monument. Journal of the Arizona-Nevada Academy of Science 15:70.

Wolfe, M. L., L. C. Ellis, and R. MacMullen. 1989. Reproductive rates of feral horses and burros. The Journal of Wildlife Management 53:916.

Woodward, S. L. 1979. The social system of feral asses (*Equus asinus*). Zietschrift für Tierpsychologie 49:304–316.

Woodward, S., and R. Ohmart. 1976. Habitat use and fecal analysis of feral burros (*Equus asinus*), Chemehuevi Mountains, California, 1974. Journal of Range Management 29:482–485.

D. BIOGRAPHICAL SKETCH

BLM Wild Horse and Burro Program

Name: Kathryn A. Schoenecker Title: Ecologist

Education:	Degree	Year	Scientific Field
Colorado State University, Ft.Collins	Ph.D	2012	Ecology
University of Arizona, Tucson	M.S.	1997	Wildlife Biology
University of Wisconsin, Madison	B.A	1987	International Relations,

(Includes 1 year at Friedrich Wilhelm Universität, Bonn, West Germany)

Honors/Awards:
USGS Star Award, 2015
USGS Aviation Safety Award, 2013
NPS Regional Director's Award for Excellence in Natural Resources Research, 2006
IUCN Bison Specialist Working Group, 2006-present
BLM Science Appreciation Award, 2001
USGS Performance Awards: 1999-2014

Major Research Interest:
Ungulate population dynamics and ecology; Population estimation techniques; Interspecific interactions of ungulates; Grazing ecology of large herbivores.

Role in Proposed Project (be specific):
- Project Lead
- Study design, data collection, data analyses, Bayes modeling, and publications

Previous and Current Research Support Relating to the Current Proposal:
- Wild horse impacts in habitat at the Sheldon-Hart NWR, 2012-2013; $25K/yr
- Wild horse demography, behavior, and population estimation in the Pryor Mountain Wild Horse Range, 1997-2004 (Cyclical base; $185K/yr)
- Re-vegetation of the common corrals in BICA, 2006 (Rapid Response; $40K)
- Development of a population estimation technique for elk (*Cervus elaphus*) in Rocky Mountain National Park, Colorado (NRPP; $70K/yr)
- Determining population size of bighorn sheep in Rocky Mountain National Park using fecal DNA, 2008-2011 (POBS; $65K/yr)
- Grazing ecology of elk and bison in the Great Sand Dunes National Park—Baca National Wildlife Refuge complex of lands, 2005-2009 (NPS NRPP; $150K/yr)
- Habitat interactions of wild horses and bighorn sheep in the PMWHR and Bighorn Canyon National Recreation Area, 2001-2003 (NRPP; $70K/yr)

Research and/or Professional Experience:
2006-2015: 10 years' experience leading the Ungulate Ecology Research Project for the USGS Fort Collins Science Center.
1997-2015: 18 years' experience as an ungulate ecologist at FORT.

Relevant Publications:

Schoenecker, K.A., L.C. Zeigenfuss, and S.C. Nielsen. 2015. Selection of vegetation types and density of bison in an arid ecosystem. Journal of Wildlife Management: *in press.*

Schoenecker, K.A., and B.C. Lubow. 2015. Assessing the contributions of multiple sources of error correction in a hybrid population estimation model for elk (*Cervus elaphus*) inhabiting a cold desert ecosystem. Journal of King Saud University Science, Special Issue on Arid Ecosystems: *in press.*

Schoenecker, K.A., S.R.B. King, M. Nordquist, N. Deitich, Q. Kao. Chapter 4: Habitat selection and diet of equids, *In* Ransom, J.I. and P. Kaczensky, Eds., Wild Equids - Ecology, Management, and Conservation. *In press for spring 2016 release.* Johns Hopkins University Press, Baltimore, USA.

Mask, T.A., K.A. Schoenecker, A.J. Kane, J.I. Ransom, and J.E. Bruemmer. 2015. Serumantibody immunoreactivity to equine zona protein after SpayVac™ vaccination. Theriogenology 84(2):261 – 267.

Schoenecker, K.A., M.K. Watry, L.E. Ellison, M.K. Schwarz, and G.L. Luikart. 2015. Estimating bighorn sheep (*Ovis canadensis*) abundance using noninvasive sampling at a mineral lick in a National Park wilderness area. Western North American Naturalist 75:181-191.

Wockner, G., Boone, R., Schoenecker, K.A., and Zeigenfuss, L.C. 2014. Modeling elk and bison carrying capacity for Great Sand Dunes National Park, Baca National Wildlife Refuge, and The Nature Conservancy's Medano Ranch, Colorado: U.S. Geological Survey Open-File Report 2014–1200, 23 p.

Zeigenfuss, L.C., K.A. Schoenecker, J.I. Ransom, D.I. Ignizio, and T. Mask. 2014. Grazer biomass and seasonal precipitation influence vegetation production in a Great Basin Ecosystem. Western North American Naturalist 74(3): 286–298.

Schoenecker, K.A. 2012. Ecology of bison, elk, and vegetation in an arid ecosystem. PhD Dissertation. Colorado State Univeristy. 91pp.

Schoenecker, K.A., J.E. Roelle, T.A. Mask, and S.S. Germaine. 2013. Annual report for 2012 wild horse research and field activities. USGS Admin. Report, 19 p.

Roelle, J.E., Singer, F.J., Zeigenfuss, L.C, Ransom, J.I., Coates-Markle, L., Schoenecker, K.A. 2010. Demography of the Pryor Mountain Wild Horses 1993–2007. USGS Scientific Investigations Report 2010–5125.

Singer, F.J. and K.A. Schoenecker, compilers. 2002. Managers summary: Ecological studies of the Pryor Mountain Wild Horse Range, 1992-1997. U.S. Geological Survey, Midcontinent Ecological Science Center, Fort Collins, CO. 113pp.

D. BIOGRAPHICAL SKETCH

BLM Wild Horse and Burro Program
Proposal for Collaborative Research Effort

Privileged Communication

Name: Sarah R.B. King Title: Research Scientist I

Education (Begin with baccalaureate training and include postdoctoral):

Institution and Location	Degree	Year Conferred	Scientific Field
QMW, University of London	B.Sc. (Hons.)	1996	Zoology and Ecology
Queen Mary, University of London	Ph.D.	2002	Behavioral Ecology
University of Colorado	Post-doc	2013	Ecology

Honors/Awards:
IUCN Equid Specialist Group (since 1999); Coordinator of the Equid Red List Authority for the IUCN (since January 2013); Conservation Fellow of the Zoological Society of London (since 2006); Outstanding Team Award, University of Arizona (2003); almost $400,000 in research grants.

Major Research Interest:
Mammal behavioral ecology: home ranges, habitat use, social behaviour, and climate change effects

Role in Proposed Project (be specific):
Co-Investigator:

- Study design
- Data collection
- Data analyses and interpretation
- Publications

Previous and Current Research Support Relating to the Current Proposal:
Scholarship to attend the Wild Equid Conference 2012, Vienna, Austria (Center for Collaborative Conservation: $550)
Co-PI - Study of sympatric wild and domestic herbivores, plus local community development (2009-2013, European Commission: $300,000)
Co-PI - Census of bird species in western Mongolia (2008, RSPB: $1,125; Idea Wild (in-kind): $740)
PI - Study of the behavioral ecology of Przewalski's horses reintroduced to Mongolia, 1998-2002 (Marwell Preservation Trust: $1,600; FRPH (in kind): $5,000; Dinam Charitable Trust: $400; IFAW: $1,600)

Research and/or Professional Experience

2013-present	Research Associate III to Research Scientist I – Colorado State University, CO
2010-2013	Postdoctoral Research Associate – University of Colorado, CO
2006-2010	Project Manager – Association TAKH, France
2005-2006	Project Manager – Zoological Society of London's Steppe Forward Programme, Mongolia
2003-2005	Wildlife Biologist, Senior – Mount Graham Red Squirrel Monitoring Program, University of Arizona, AZ

Recent relevant (horse related) publications:

King, S.R.B. & Gurnell, J. In review. 'Vigilance and its links to social cohesion in a reintroduced equid'. *Behavioural Ecology*.

Schoenecker, K.A, King, S.R.B., Nordquist, M., Dejid, N., & Cao, Q. In review. 'Habitat and diet of equids'. In: Ransom, J. & Kaczensky, P. (eds). *Wild Equids: Ecology, Management, and Conservation*. Johns Hopkins University Press.

Moehlman, P. & King, S.R.B. In review. 'Conservation of threatened wild equids'. In: Ransom, J. & Kaczensky, P. (eds). *Wild Equids: Ecology, Management, and Conservation*. Johns Hopkins University Press.

King, S.R.B., Asa, C., Pluháček, J., Houpt, K. & Ransom, J. In press. 'The behavior of horses, zebras, and asses'. In: Ransom, J. & Kaczensky, P. (eds). *Wild Equids: Ecology, Management, and Conservation*. Johns Hopkins University Press.

King, S.R.B. 2013 'Przewalski's horses and red wolves: importance of behavioral research for species brought back from the brink of extinction'. In: Bekoff, M. (ed). *Ignoring Nature No More: The Case for Compassionate Conservation*. University of Chicago Press, Chicago, USA.

Olléová, M., Pluháček, J. & King, S.R.B. 2012. 'Effect of social system on allosuckling and adoption in zebras'. *Journal of Zoology*. 288: 127-134.

Boyd, L. & King, S.R.B. 2011. *Equus ferus*. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2.

King, S.R.B. & Gurnell, J. 2010. 'Effects of fly disturbance on the behaviour of a population of reintroduced Przewalski horses (*Equus ferus przewalskii*) in Mongolia'. *Applied Animal Behaviour Science*. 125: 22-29.

Bourjade, M., Tatin, L., King, S.R.B. & Feh, C. 2009. 'Behavioural correlates of early reproductive success in Przewalski stallions'. *Ethology, Ecology & Evolution*. 21: 1-14.

Tatin, L., King, S.R.B., Munkhtuya, B., Hewison, A.J.M. & Feh, C. 2009. 'Demography of a socially natural herd of Przewalski's horses: an example of a small, closed population'. *Journal of Zoology*. 277: 134-140.

D. BIOGRAPHICAL SKETCH

BLM Wild Horse and Burro Program
Proposal for Collaborative Research Effort

Privileged Communication

Name: Linda C. Zeigenfuss Title: Ecologist

Education (Begin with baccalaureate training and include postdoctoral):

Institution and Location	Degree	Year Conferred	Scientific Field
Mount Holyoke College	B.A.	1989	Biology
Colorado State University	M.Sc.	1993	Forest Ecology

Honors/Awards:
USGS Performance Awards 1997-2014

Major Research Interest:
Ungulate-plant ecology including research of grazing effects on riparian and aspen ecosystems, development of monitoring programs for ungulate herbivory, and habitat selection of ungulates and other mammals.

Role in Proposed Project (be specific):
Analysis of horse habitat selection data and preparing manuscripts for publication

Previous and Current Research Support Relating to the Current Proposal:

- Wild horse impacts in habitat at the Sheldon-Hart NWR, CO-I, USGS-FWS SSP funds, 2012-2013; $25K/yr
- Wild horse demography, behavior, and population estimation in the Pryor Mountain Wild Horse Range, 1997-2004 (Cyclical base; $185K/yr)

Research and/or Professional Experience

Ecologist/Wildlife Biologist, USGS, Fort Collins Science Center, 1997-present.

Research Associate (Project Manager), Natural Resource Ecology Lab, Colorado State University, Fort Collins, CO. 1994-97.

My research emphasis over the past 20 years has focused on studies of plant-ungulate interactions. My recent work has involved field sampling, site selection, study design, data analysis and co-authorship of manuscripts on several multi-year research projects on native ungulates in national parks in the Western U.S., including: elk herbivory effects on plant communities of Rocky Mountain National Park; development and monitoring vegetation responses to elk management in Rocky Mountain and Great Sand Dunes National Parks; bison and elk grazing ecology in Great Sand Dunes National Park; habitat selection, herbivory effects, and effects on nitrogen cycling of ungulates in Jackson Valley and Grand Teton National Park; impacts of prescribed burning and grazing on woody shrub communities of Wind Cave National Park; and release of willows from elk browsing pressure following wolf reintroduction in Yellowstone National Park. The majority of these studies have involved use of exclosures to experimentally manipulate grazing and browsing levels

Relevant Publications:

Zeigenfuss, L.C., K.A. Schoenecker, J.I. Ransom, D.A. Ignizio and T. Mask. 2014. Influence of nonnative and native ungulate biomass and seasonal precipitation on vegetation production in a great basin ecosystem. Western North American Naturalist. 74(3): 286-298.

Roelle, J.E., F.J. Singer, L.C. Zeigenfuss, J.I. Ransom, L. Coates-Markle, and K.A. Schoenecker. 2010. Demography of the Pryor Mountain Wild Horses, 1993-2007: U.S. Geological Survey Scientific Investigations Report 2010-5125. 31 p.

Zeigenfuss, L.C., and Schoenecker, K.A., 2015, Development of a grazing monitoring program for Great Sand Dunes National Park: U.S. Geological Survey, Open-File Report 2015–1136, 44 p.

Wockner, G., R. Boone, K.A. Schoenecker, and L.C. Zeigenfuss. 2015. Modeling elk and bison carrying capacity for Great Sand Dunes National Park, Baca National Wildlife Refuge, and The Nature Conservancy's Medano Ranch, Colorado. Open-file Report 2014–1200. Reston, VA: U.S. Geological Survey. 23 p.

Zeigenfuss, L.C., T. Johnson, and Z. Wiebe. 2011. Monitoring plan for vegetation responses to elk management in Rocky Mountain National Park. Open-File Report 2011–1013. U.S. Geological Survey. 85 p.

Zeigenfuss, L.C., K.A. Schoenecker, and L. VanAmberg. 2011. Ungulate herbivory on alpine willow in the Sangre de Cristo Mountains of Colorado. Western North American Naturalist 71(1):86-96.

Schoenecker, K.A., F.J. Singer, L.C. Zeigenfuss, D. Binkley, and R.S.C. Menezes. 2004. Effects of elk herbivory on vegetation and nitrogen processes. Journal of Wildlife Management 68(4): 837-849.

Zeigenfuss, L.C., F.J. Singer, S. A. Williams, and T. L. Johnson. 2002. Influences of herbivory and water on willow in elk winter range. Journal of Wildlife Management 66:788-795.

Singer, F.J., and L. C. Zeigenfuss. 2002. Influence of trophy hunting and horn size on mating behavior and survivorship of mountain sheep. Journal of Mammalogy 83:682-698.

Singer, F.J., L. Zeigenfuss and L. Spicer. 2001. The role of patch size, disease and movements in the rapid extinction of bighorn sheep. Conservation Biology. 12:1347-1354.

Zeigenfuss, L.C., F.J. Singer, and M.A. Gudorf. 2000. Test of a modified habitat suitability model for bighorn sheep. Restoration Ecology 8 (4S):38-46.

Singer, F.J., E. Williams, M.W. Miller, and L. C. Zeigenfuss. 2000. Population growth, fecundity, and survivorship in recovering populations of bighorn sheep. Restoration Ecology 8 (4S):75-84.

D. BIOGRAPHICAL SKETCH

BLM Wild Horse and Burro Program
Proposal for Collaborative Research Effort

Name: Kate R. Searle Title: Ecological Modeler

Education:

Institution and Location	Degree	Year	Scientific Field
CSU, Fort Collins	Ph.D.	2004	Spatial heterogeneity in foraging decisions of large herbivores.
University of East Anglia, Norwich, England	B.S. (First Class Honours)	1999	Ecology

Honors/Awards/Service:
Associate Editor for Animal Conservation
Invited reviewer for book 'Bayesian Statistics: A Primer for Ecologists' Hobbs & Hooten.
Member of the National Centre for Statistical Ecology, UK.
Member of the Applied Statistics Network, Centre for Ecology and Hydrology.
Student Liaison Officer for Centre for Ecology and Hydrology, Edinburgh.
Member of Society for Conservation Biology, British Ecological Society.

Major Research Interest:
My research focuses on the effects of environmental change on wildlife behavior, populations and distributions. By combining contemporary ecological techniques with an understanding of resource-consumer dynamics in heterogeneous environments, I aim to gain mechanistic, process-driven understanding of ecological systems through both statistical modelling and more applied management-orientated experiments.

Role in Proposed Project (be specific):
Co-Investigator:

- Data analyses and interpretation, Bayes population modeling, publication

Previous and Current Research Support Relating to the Current Proposal:
NERC Marine Ecosystems Research Program. £180,000. Modelling distribution and behaviour of marine top predators.
Scottish Government Project, At-sea turnover of breeding seabirds (MSQ-0103).
Scottish Government Project CR/2012/03: Population consequences of displacement from proposed offshore wind energy developments for seabirds breeding at Scottish spas. £98,000.
Scottish Government Project: Population dynamics of forth and tay breeding seabirds: review of all available models and modelling of key breeding populations. £51,000.
Centre for Ecology and Hydrology: Environmental Assessment and Risk - Understanding role of wild ruminants in vector-borne disease incursions and mapping how seasonal and spatial hotspots of contact between wild and domestic ruminants and vectors alter with landscape and climate change.

NSF grants DEB-1146166, 1146194, 1146368 (Total $950,346) ‘Collaborative Research: Modelling the Tradeoffs within Food-, Fear-, and Thermal-Scapes to Explain Habitat Use by Mammalian Herbivores.

Research and/or Professional Experience:

Ecological Modeller, Centre for Ecology & Hydrology, Edinburgh, Scotland (2010 to present). Specialising in population dynamics, resource-consumer dynamics, foraging behaviour, vector-borne disease and invasive pathogens.

USGS Ecosystem dynamics group, Fort Collins Science Centre, Colorado (2009). State-space model for population dynamics of the San Luis Valley bison population in relation to climate, and aerial surveying of large ungulates.

Colorado Division of Wildlife, Fort Collins, Colorado (2009). Collaborative research using remote-sensing to predict diet quality and body condition of mule deer in western Colorado in response to temporal and spatial variation in resources.

Post Doctoral Fellow at Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO 80523-1499 (2007-2010). Conducting research into the effects of fragmentation on consumer-resource dynamics in environments varying in space and time.

Post Doctoral Fellow at the CSIRO Sustainable Ecosystems Division, Townsville, Australia (2005 to 2007). Researching the effect of cattle grazing on spatial patterns of vegetation and soil components in grazed semi-arid tropical rangelands, with implications for ecosystem function and integrity.

Skills, software and training: Hierarchical Bayesian methods, Information theoretics and likelihood, Remote Sensing, R, BUGS, Matlab, SAS, ArcMap; Crocodile awareness training, 4WD, First Aid, EPA pesticide certified, Aviation Training (B3): combination helicopter/airplane safety, aerial surveying of large ungulates.

Recent relevant publications:

Searle, K. R., C. Anderson, C. Bishop, N. T. Hobbs, M. B. Rice. 2015. Asynchronous vegetation phenology enhances winter body condition of Mule Deer (*Odocoileus hemionus*). *Oecologia, 179(2):377-91.*

Stephen Freeman, Kate Searle, Maria Bogdanova, Sarah Wanless & Francis Daunt. 2014. Population dynamics of Forth and Tay breeding seabirds: review of available models and modelling of key breeding populations - Final Report. http://www.gov.scot/Resource/0044/00449072.pdf.

Searle, K.R., Mobbs, D., Butler, A., Bogdanova, M., Freeman, S., Wanless, S. & Daunt, F. 2013. Population Consequences of Displacement from Proposed Offshore Wind Energy Developments for Seabirds Breeding at Scottish SPAs (CR/2012/03). Report to Marine Science Scotland. http://www.gov.scot/Resource/0040/00404982.pdf.

Searle, K. R., Simon Carpenter, Adam Butler, Anthony Wilson, James Barber, Francesca Stubbins, Eric Denison, Christopher Sanders, Philip Mellor, Noel Nelson, Simon Gubbins, & Bethan V. Purse. 2014. Drivers of *Culicoides* phenology: how important is species-specific variation in determining disease policy? *PLOS One*, November 11, 2014, DOI: 10.1371/journal.pone.0111876.

Bessell, P. R., Rob Robinson, Nick Golding, Lisa Boden, Kate R. Searle, Ian G. Handel, Bethan V. Purse & B. Mark de Bronsvoort. 2014. Quantifying the risk of introduction of West Nile Virus into Great Britain by migrating passerine birds. *Transboundary and Emerging Diseases,* doi:10.1111/tbed.12310.

Bessell, P., Auty, H., Searle, K. R., Handel, I., Purse, B. V., and M. Bronsvoort. 2014. Impact of temperature, feeding preference and vaccination on Schmallenberg virus transmission in Scotland. *Nature: Scientific Reports, 4(5746) DOI 10.1038/srep05746.*

Bessell, P. R., Kate R. Searle, Harriet K. Auty, Ian G. Handel, Bethan V. Purse & B. Mark de Bronsvoort. 2013. Epidemic potential of an emerging vector-borne disease in a marginal environment: Schmallenberg in Scotland. *Nature: Scientific Reports* 3(1178)1-10 DOI: 10.1038/srep01178.

Young, J.C., A Jordan; K. R. Searle; A Butler; P Simmons; A D. Watt. 2013. Framing scale in participatory biodiversity management may contribute to more sustainable solutions. *Conservation Letters* 6-5:333-340.

Young, J. C., A. Jordan, K. R. Searle, A. Butler, D. S. Chapman, P. Simmons and A. D. Watt. 2013. Does stakeholder involvement really benefit biodiversity conservation? *Biological Conservation* 158(2013): 359-370.

Purse, B. V., P. Graeser, K. R. Searle, C. Edwards and C. Harris. 2013. Challenges in predicting invasive reservoir hosts of emerging pathogens: mapping *Rhododendron ponticum* as a foliar host for *Phytophthora ramorum* and *Phytophthora kernoviae* in the UK. *Biological Invasions* 15(3):529-545.

Searle, K. R., B. V. Purse, A. Blackwell, D. Falconer, M. Sullivan and A. Butler. 2013. Environmental drivers of insect phenology across space and time: *Culicoides* in Scotland as a case study. *Bulletin of Entomological Research, 103:155-170.*

Burthe, S., Butler, A., Searle, K. R., Hall, S., Thackeray, S., and S. Wanless. 2012. Consequences of increased winter births in a large aseasonally breeding mammal (*Bos taurus*) in response to climate change. *Journal of Animal Ecology* 80(6):1134-1144. DOI: 10.1111/j.1365-2656.2011.01865.x

Purse, B. V. & K. R. Searle. 2013. Study of the epidemiology of *Phytophthora ramorum* and *Phytophthora kernoviae* in managed gardens and heathland in Scotland. Report to The Scottish Government.

Searle, K. R., N. T. Hobbs and S. T. Jaronski. 2010. Asynchrony, fragmentation, and scale determine benefits of landscape heterogeneity to mobile herbivores. *Oecologia* 163(3):_815-824. DOI: 10.1007/s00442-010-1610-8

Searle, K. R., L. P. Hunt, and I. J. Gordon. 2010. Individualistic herds: individual variation in herbivore foraging behaviour and application to rangeland management. *Applied Animal Behaviour Science* 122(1):1-12. DOI: 10.1016/j.applanim.2009.10.005

Searle, K. R., I. J. Gordon, and C. J. Stokes. 2009. Hysteretic responses to grazing in a semi-arid rangeland. *Rangeland Ecology and Management 62(2):136-144.*

Searle, K. R., C. J. Stokes, and I. J. Gordon. 2008. When foraging and fear meet: using foraging hierarchies to inform assessments of landscapes of fear. *Behavioral Ecology 19(3): 475-482.*

Searle, K. R. 2008. Foraging: behaviour and ecology. *Quarterly Review of Biology 83(2): 208-209.* Book review.

Searle, K. R., N. T. Hobbs, and I. J. Gordon. 2007. It's the "Foodscape", not the landscape: using foraging behaviour to make functional assessments of landscape condition. Special edition ('Behavioural Indicators and Conservation') for *Israel Journal of Ecology and Evolution 53(3-4):297-316.*

Searle, K. R., and L. A. Shipley. 2007. The comparative feeding behaviour of large browsing and grazing herbivores. Chapter 5, pages 117-148 *in* Ecology of Browsing and Grazing, Eds. I. J. Gordon and H. H. T. Prins. Series: Ecological Studies, Vol. 195, Springer Berlin Heidelberg.

E. FACILITIES STATEMENT

BLM Wild Horse and Burro Program
Proposal for Collaborative Research Effort

Privileged Communication

The USGS Fort Collins Science Center and the Natural Resource Ecology Laboratory (NREL) at Colorado State University (CSU) will provide office space, information technology resources, modeling support, and administrative support.

F. DETAILED BUDGET FOR EACH 12 MONTH PERIOD

YEAR 1, Budget for *both* Lake Pleasant HMA and Sinbad HMA: AUG 2015 TO SEP 2016

Salary & Wages (Describe % effort or hours for each person)

Item	USGS In-kind	BLM in-kind	Project Cost
Kate Schoenecker (15% time)	15,000		
Sarah King (5% time)	3,000		
GS 7/9 Tech/crew leader (20% time) [68K total cost]			13,600
Volunteers (camping rate per diem)	1,800		
1 Field tech @$3.5K/mo./tech for 6 months (Mar-Aug)			21,000
SUBTOTAL	19,800		34,600

Equipment & Supplies

Item	USGS In-kind	BLM in-kind	Project Cost
Radio collars (20 GPS @ $3600/each= $72,000,	[1]35000		46,000
Radio collars (40 Vertex Survey @$800 each)	[2]32,000		
Annual data usage plan (Global star and Iridium)			3,000
1 Telemetry Receiver @$1,200			1,200
Binoculars @$250			250
SUBTOTAL	67,000		50,450

Animal Costs (Including board and maintenance)

Item	USGS In-kind	BLM in-kind	Project Cost
BLM wild burro gather in Sinbad (Jan 2016; $100K) and water trapping in Lake Pleasant (April 2016; $50K) to deploy radio collars.		$150,000	0
SUBTOTAL		$150,000	0

Miscellaneous Costs– Itemize

Item	USGS In-kind	BLM in-kind	Project Cost
Lab analysis fecal estradiol, 50 jennies @$120 each			6,000
Aerial survey pre gather/water trap (Jan/Mar. 2016) @$15k/HMA	[2]30,000		
Aerial survey post gather/water trap (Feb/. Apr. 2016) @ 18K/HMA	[2]36,000		
Travel: pre gather Aerial survey; 2 USGS observers for 4 nights @ $170/night= $1360 + airfare@$450 each= $900 x 2 HMAs	[2]4,520		
Travel: post gather Aerial survey; 2 USGS observers for 4 nights @ $170 each= $1360, airfare@$450 each= $900 x 2 HMAs	[2]4,520		
Travel: radio collar and mortality check 1x/month X 2 months (Jan-Feb, 2016); Airfare=$450, 3 nights @$170 each, rental vehicle or BLM GOV= $675. [total=$1635 x2 trips] x 1 HMA (Sinbad)			3,270
Travel for summer foaling : 3K/month x 6 mos (Sinbad) and x 5 mos (Lake Pleasant).			33,000
SUBTOTAL			42,270

[1] Funding from the radio collar project.
[2] Funding from the Burro Aerial Survey Techniques study (duplicate use of radio collars and surveys)

Project SubTotal: $ 127,320
Indirect Costs: $ 46,339
TOTAL: $ 173,659
AMOUNT REQUESTED OF BLM: $ 173,659

YEAR 2, Budget for *both* Lake Pleasant HMA and Sinbad HMA: OCT 2016 TO SEP 2017

Salary & Wages (Describe % effort or hours for each person)

Item	USGS In-kind	BLM in-kind	Project Cost
Kate Schoenecker (15% time)	15,000		
Sarah King (5% time)	3,000		
GS 7/9 Tech/crew leader (20% time) [68K total cost]			13,600
Volunteers (camping rate per diem)	1,800		
1 Field techs @$3.5K/mo./tech for 6 months (Mar-Aug 2017)			21,000
SUBTOTAL	19,800		34,600

Equipment & Supplies

Item	USGS In-kind	BLM in-kind	Project Cost
Annual data usage plan (Global star and Iridium)			3,000
SUBTOTAL			3,000

Animal Costs (Including board and maintenance)

Item	USGS In-kind	BLM in-kind	Project Cost
Gathers or water trapping		0	0
Annual aerial population survey ($15K/HMA)	[2]30,000		
SUBTOTAL		0	0

Miscellaneous Costs– Itemize

Item	USGS In-kind	BLM in-kind	Project Cost
Lab analysis fecal estradiol, 50 jennies @$120 each			6,000
Travel: annual Aerial survey; 2 USGS observers for 4 nights @ $170 each= $1360, airfare@$450 each= $1100 x 2 HMAs	[2]4,520		
Travel: radio collar and mortality check 1x/month (Oct 2016-Feb 2017) X 6 months; Airfare=$450, 3 nights @$170 each, rental vehicle or BLM GOV= $675. [total=$1635 x6 trips x 2 HMAs]			19,620
Travel for summer foaling for 6 months (Mar-Sep 2017): $3K/month x 6 months x 2 HMAs			36,000
SUBTOTAL			61,620

[1] Funded by the radio collar project.
[2] Funded by the Burro Aerial Survey study (duplicate use of radio collars, surveys, and travel for personnel)

Project SubTotal: $ 99,220
Indirect Costs: $ 36,112
TOTAL: $ 135,332
AMOUNT REQUESTED OF BLM: $135,332

YEAR 3, Budget for *both* Lake Pleasant HMA and Sinbad HMA: OCT 2017 TO SEP 2018

Salary & Wages (Describe % effort or hours for each person)

Item	USGS In-kind	BLM in-kind	Project Cost
Kate Schoenecker (15% time)	15,000		
Sarah King (5% time)	3,000		
GS 7/9 Tech/crew leader (20% time) [68K total cost]			13,600
Volunteers (camping rate per diem)	1,800		
1 Field techs @$3.5K/mo./tech for 6 months (Mar-Aug 2018)			21,000
SUBTOTAL	19,800		34,600

Equipment & Supplies

Item	USGS In-kind	BLM in-kind	Project Cost
Annual data usage plan (Global star and Iridium)			3,000
SUBTOTAL			3,000

Animal Costs (Including board and maintenance)

Item	USGS In-kind	BLM in-kind	Project Cost
Gathers or water trapping		0	0
Annual aerial population surveys ($15K/HMA)	0	*30,000	0
SUBTOTAL		30,000	0

Miscellaneous Costs– Itemize

Item	USGS In-kind	BLM in-kind	Project Cost
Lab analysis fecal estradiol, 50 jennies @$120 each			6,000
Travel: annual Aerial survey; 2 USGS observers for 4 nights @ $170 each= $1360, airfare@$450 each= $900 x 2 HMAs	[2]4,520		
Travel: radio collar and mortality check 1x/month (Oct 2017-Feb 2018) X 6 months; Airfare=$450, 3 nights @$170 each, rental vehicle or BLM GOV= $675. [total=$1635 x6 trips x 2 HMAs]			19,620
Travel for summer foaling for 6 months (Mar-Sep 2018): $3K/month x 6 months x 2 HMAs			36,000
SUBTOTAL			61,620

[1] Funded by the radio collar project.
[2] Funded by the Burro Aerial Survey study (duplicate use of radio collars, surveys, and travel for personnel)
*We are requesting each HMA cover the cost of one aerial population survey during the 5 year study.

Project SubTotal: $ 99,220
Indirect Costs: $ 36,112
TOTAL: $ 135,332
AMOUNT REQUESTED OF BLM: $135,332

YEAR 4, Budget for *both* Lake Pleasant HMA and Sinbad HMA: OCT 2018 TO SEP 2019

Salary & Wages (Describe % effort or hours for each person)

Item	USGS In-kind	BLM in-kind	Project Cost
Kate Schoenecker (15% time)	15,000		
Sarah King (5% time)	3,000		
GS 7/9 Tech/crew leader (20% time) [68K total cost]			13,600
Volunteers (camping rate per diem)	1,800		
1 Field techs @$3.5K/mo./tech for 6 months (Mar-Aug)			21,000
SUBTOTAL	36,800		34,600

Equipment & Supplies

Item	USGS In-kind	BLM in-kind	Project Cost
Annual data usage plan (Global star and Iridium)			3,000
SUBTOTAL	67,000		3,000

Animal Costs (Including board and maintenance)

Item	USGS In-kind	BLM in-kind	Project Cost
Gathers or water trapping		0	0
Annual aerial population survey	[3]30,000	0	0
SUBTOTAL	30,000	0	0

Miscellaneous Costs– Itemize

Item	USGS In-kind	BLM in-kind	Project Cost
Lab analysis fecal estradiol, 50 jennies @$120 each			6,000
Travel: annual Aerial survey; 2 USGS observers for 4 nights @ $170 each= $1360, airfare@$450 each= $900 x 2 HMAs			4,520
Travel: radio collar and mortality check 1x/month (Oct 2018-Feb 2019) X 6 months; Airfare=$450, 3 nights @$170 each, rental vehicle or BLM GOV= $675. [total=$1635 x6 trips x 2 HMAs]			19,620
Travel for summer foaling for 6 months (Mar-Sep 2019): $3K/month x 6 months x 2 HMAs			36,000
SUBTOTAL			66,140

[1] Funded by the radio collar project.
[2] Funded by the Burro Aerial Survey study (duplicate use of radio collars, surveys, and travel for personnel)
[3]Funded by USGS; base WH&B program.

Project SubTotal: $ 103,740
Indirect Costs: $ 37,757
TOTAL: $ 141,497
AMOUNT REQUESTED OF BLM: $141,497

YEAR 5; Budget for *both* Lake Pleasant HMA and Sinbad HMA: OCT 2019 TO SEP 2020

Salary & Wages (Describe % effort or hours for each person)

Item	USGS In-kind	BLM in-kind	Project Cost
Kate Schoenecker (15% time)	15,000		
Sarah King (5% time)	3,000		
GS 7/9 Tech/crew leader (20% time) [68K total cost]			13,600
Linda Zeigenfuss (habitat modeling, 180 hours)			9,000
Kate Searle (population modeling, both herds)			12,000
Volunteers (camping rate per diem)	1,800		
1 Field techs @$3.5K/mo./tech for 6 months (Mar-Aug 2020)			21,000
SUBTOTAL	36,800		55,600

Equipment & Supplies

Item	USGS In-kind	BLM in-kind	Project Cost
Annual data usage plan (Global star and Iridium)			3,000
SUBTOTAL			3,000

Animal Costs (Including board and maintenance)

Item	USGS In-kind	BLM in-kind	Project Cost
Gathers or water trapping		0	0
Annual aerial population survey (@ 15K/HMA)		0	30,000
SUBTOTAL		0	30,000

Miscellaneous Costs– Itemize

Item	USGS In-kind	BLM in-kind	Project Cost
Lab analysis fecal estradiol, 50 jennies @$120 each			6,000
Travel: annual Aerial population survey; 2 USGS observers for 4 nights @ $170 each= $1360, airfare@$450 each= $900 x 2 HMAs			4,520
Travel: radio collar and mortality check 1x/month (Oct 2019-Feb 2020) X 6 months; Airfare=$450, 3 nights @$170 each, rental vehicle or BLM GOV= $675. [total=$1635 x6 trips x 2 HMAs]			19,620
Travel for summer foaling for 6 months (Mar-Sep 2020): $3K/month x 6 months x 2 HMAs			36,000
Data analyses and publication costs	8,000		
SUBTOTAL	8,000		66,140

[1] Funded by the radio collar project.
[2] Funded by the Burro Aerial Survey study (duplicate use of radio collars, surveys, and travel for personnel)

Project SubTotal: $ 154,740
Indirect Costs: $ 55,861
TOTAL: $ 210,601
AMOUNT REQUESTED OF BLM: $210,601

G. HUMANE CARE AND USE OF ANIMALS

BLM Wild Horse and Burro Program

This study will require restraining wild burro jennies within a holding panel for the fitting of radio collars. We will not use chemical immobilization for radio collaring.

No other direct contact will be made with living animals. Collars will be designed to drop off at the end of the study period. All procedures will follow protocols approved by the USGS Animal Care and Use Committee.

Protocol number: ***FORT IACUC 2015-10***

Title of proposal: Field use and testing of radio telemetry collars and radio tags on free-roaming wild horses and burros in the Western United States.

Investigators: Drs. K.A. Schoenecker, and S.R.B. King

Pursuant to procedures established by the Bureau of Land Management, Wild Horse and Burro Research Program, I certify that the above described protocol follows guidelines set forth in the National Institutes of Health "Guide for the Care and Use of Laboratory Animals" (#85-23) and the "Animal Welfare Act of 1966" (PL 89-544) as amended.

Signature: (*Please see attached signature page)* Date __7-13-2015_

Name: ______Bill Iko______________________
Chair, Institutional Animal Care and Use Committee

Name of Institution: U.S. Geological Survey, Fort Collins Science Center, Animal Care and Use Committee_

G. HUMANE CARE AND USE OF ANIMALS

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Fort Collins Science Center
2150 Centre Avenue, Bldg C
Fort Collins, CO 80526-8118

July 13, 2015

To: Kate Schoenecker, Sarah King, Fort Collins Science Center and Colorado State University

From: Bill Iko, FORT IACUC Chair

Re: FORT IACUC Approval of Study Plan entitled "Field use and testing of radio telemetry collars and radio tags on free-roaming wild horses and burros in the Western United States."(FORT IACUC Approval 2015-10).

After completion of preliminary review of your submission (6/17/15), PI review and resubmission (7/7/15), your FORT IACUC document has been approved (FORT IACUC Approval 2015-10). This approval is good for 3 years, at which time the PI will need to request an extension and report on the current progress of this project.

Just a reminder that the FORT IACUC has a minimum of 10 working days to complete their preliminary review. With committee review, PI review, and resubmission of amended document, this review process can take up to 20 working days (1 month), so please plan accordingly. PIs cannot start their field or laboratory research with animals until the FORT IACUC approval has been given.

Sincerely,

William M. Iko
FORT IACUC Chair