BLM Wild Horse and Burro Research
Background Materials for Advisory Board, June 2021

These materials for the June 2021 WHB Advisory Board meeting include notes about BLM-supported WHB research and a summary of BLM-supported and other research since 2005.

WHB Research and the BLM

The Department of the Interior (DOI) is guided by science in natural resource management.[1] The Bureau of Land Management (BLM) must maintain a thriving natural ecological balance on the Public Lands it stewards, protecting highly valued wild horse and burro (WHB) populations along with other resources, uses, and values on the public lands system. Wild horses and burros contribute unique value to public lands of the American West. Many WHB herds that are larger than appropriate management levels (AML) grow at rates of ~20% per year and are currently damaging ecologically sensitive habitats in and near herd management areas (HMAs). Large numbers of excess animals, relative to available natural resources, are causing lasting negative effects on riparian lands and uplands, wildlife habitat quality, and soil erosion, and are degrading landscapes' potential resilience in the face of climatic change.

High-quality research can inform management decisions and save taxpayer dollars over time. To the extent possible, the BLM applies the results of scientific research to improve WHB management, to help the BLM protect self-sustaining wild horse and burro populations, and to meet the ecological goals behind its mission.

The BLM has supported WHB-related research since shortly after passage of the WFRHBA. The largest recent pulse of BLM-funded WHB research was in fiscal year (FY) 2015, supporting multiple studies to develop and test fertility control methods, including studies of silicone IUDs, new fertility control vaccines, and how GonaCon vaccine boosters increase long-term effectiveness. The BLM has supported these and other fertility control studies since FY2015, and has initiated other new research projects since that time. Some studies addressing demography, behavior, genetics, and other topics were also funded in and since FY 2015 (see table of research projects, below).

Peer-reviewed research can provide transparent scientific results that inform management and have the potential to improve public trust in the BLM's decisions. The US Geological Survey (USGS), US Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS), USDA National Wildlife Research Center (NWRC), National Park Service (NPS), US Forest Service, research universities, and non-governmental organizations have been important partners in formulating and carrying out WHB research. The USGS is the research agency for the Department of the Interior and

1 Presidential Order 13990. Executive Order on Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis. January 20, 2021.

has contributed much to WHB research studies since 2001. The BLM relies on USDA APHIS Veterinary Services, whose mission includes ensuring the humane care and treatment of animals, for advice on WHB welfare, veterinary care, and potential study design. The BLM also collaborates with other agencies and organizations to support studies that address climate adaptation and resilience, wildlife, land use, fire, and ecosystem restoration.

The BLM WHB Research Advisory Team Structure

For WHB-related studies involving any level of BLM support or permitting, or which might include or affect living WHB or use of their tissues, all research proposals and inquiries must be sent to the WHB Program's Research Advisory Team (BLM IM 2005-204). The team plays a role in ensuring that any BLM-supported, WHB-related research meets high standards of scientific quality, including with respect to animal welfare, study design and inference strength. The team reviews proposals, soliciting outside peer reviews as needed, and makes recommendations to the WHB Program Division Chief, who then approves or denies these proposals. The team monitors ongoing studies to track progress toward study objectives, encourage responsible spending, and advises the WHB Program on current research results. The team is co-chaired by the WHB program On-Range Branch Chief and the WHB Research Coordinator; other members currently include two WHB specialists, the USDA APHIS Veterinary Services advisor, and liaisons from the US Forest Service and National WHB Advisory Board. Research Advisory Team members cannot review proposals in which they have a real or perceived conflict of interest.

2005 WHB Research Strategy and 2013 National Academies of Sciences Report

The choice of research projects that the BLM has supported since 2005 have been heavily influenced by the 2005 strategic research plan[2], and by a BLM-commissioned, 2013 National Academies of Sciences (NAS) report[3]. The 2005 WHB research strategy set research goals for four topics: 1) health and handling, 2) fertility control, 3) population estimation and modeling, and 4) genetics. The 2005 strategy suggested studies to address what were key questions at that time, in each of the four listed research topics.

At the BLM's request, the NAS reviewed several aspects of the WHB program, including population growth, fertility control, inventory methods, the setting of AML, and population genetics. The 2013 NAS report recommended that the BLM use science-based tools to address program challenges including overpopulation relative to AML, and high annual growth rates. The 2013 report identified areas where the results of research could improve WHB management decisions.

Research Responsive to the 2005 WHB Research Strategy and 2013 NAS Report

The BLM has funded and collaborated on many WHB research projects addressing the priorities identified in the 2005 WHB research strategy and the 2013 NAS report. The tables below summarize known WHB research projects in the US since 2005; please contact Paul Griffin if you are aware of additional projects that should be added to this list, or updates that should be made. The BLM

[2] Bureau of Land Management Wild Horse and Burro Program. 2005. Strategic research plan; Wild Horse and Burro Management. Bureau of Land Management, in collaboration with US Geological Survey and USDA Animal and Plant Health Inspection Service. Fort Collins, Colorado.

[3] National Research Council of the National Academies of Sciences (NAS). 2013. Using science to improve the BLM wild horse and burro program: a way forward. National Academies Press. Washington, DC.

leveraged appropriated WHB Program funds to support research with practical management applications, collaborating with universities, non-governmental institutions, and state and federal agencies, some of which secured support from other funding sources.

The BLM obligated approximately $11M of research funding in FY 2015 to support projects related to fertility control, aerial surveys, ecology, demography, and genetics. These were led by leading equine science research universities, USGS, NPS, and USDA NWRC. Fertility control research proposals were in response to a 2014 BLM request for proposals (RFP), and were reviewed by the National Academies of Sciences. The studies funded in FY 2015 constitute the majority of BLM-funded WHB research in the last 10 years. Since FY 2015, a smaller number of additional, compelling research projects have been funded as WHB Program funding has allowed.

In the future, additional RFPs would be the preferred mechanism to alert the research community about any available funding. RFPs tend to foster the greatest level of competition and public transparency. If future budgets allow for it, a consistent and organized source of funding over time could keep the research community engaged, and lead to the development and testing of many more potential fertility control methods, and other advances in WHB management.

The BLM is eager to work with partners that share an interest in improving WHB management through scientific investigation, and then applying the results of research through agency actions. In the recent past, NPS, US Fish and Wildlife Service, USDA NWRC, USFS, Department of Defense, Arizona Game and Fish Department, Wyoming Department of Transportation, and Humane Society of the United States have also supported WHB research.

The BLM looks forward to seeing the results of projects that it supports as publications in peer-reviewed scientific literature, and drawing on those results in its management decisions.

The following materials include:

1. 1-page chart of BLM-supported projects, with research projects color-coded by topic;
2. 2-page description of some notable projects that were responsive to the four priority research topics identified in the 2005 WHB strategic research plan;
3. 16-page “Table of Past and Present Wild Horse and Burro Research and Related Projects,” describing projects known to BLM since 2005, listed in terms of collaborator, budget, goals, outcomes, and management implications; and
4. 6-page listing of scientific literature cited in the description and table.

Overview of Wild Horse and Burro Research & Pilot Projects Since 2005

Project numbers in the timeline refer to BLM-supported projects in the summary table that follows.

Project #	Agency / University	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1 Oocyte vaccine pen trial	USDA																		
2 Geldings field trial	USGS																		
3 Silicone IUDs pen trial	USGS																		
4 PopEquus software	USGS																		
5 Oocyte vaccine development	Colo State																		
6 GonaCon booster field trial	Colo State																		
7 Burro PZP darting field trial	HSUS																		
8 PZP Capsules development	Ohio State																		
9 PZP Adjuvant development	Purdue U																		
10 GonaCon pilot project	BLM																		
11 Genetic monitoring	TAMU																		
12 Minimally invasive sterilization[4]	UC Davis																		
13 PZP pellet vaccine trial	U Toledo																		
14 PZP-22 development	U Toledo																		
15 PZP-22 field trials	U Toledo																		
16 Spay Vac pen trials	USGS																		
17 Ecology, demography & behavior	USGS																		
18 Sage-grouse stressors	USGS																		
19 Horses and Sage-grouse	USGS																		
20 Horse demography	USGS																		
21 Burro demography	USGS																		
22 Movements in checkerboard	U Wyo																		
23 Burro-vehicle collisions	AZGFD																		
24 Infrared survey tests	USGS																		
25 Burro survey methods	USGS																		
26 Fecal DNA methods	USGS																		
27 Horse survey methods	USGS																		
28 Surveys; distance sampling	WEST																		
29 Satellite-based counts	BLM																		
30 Riparian impacts	U Idaho																		
31 Carrying capacity	USGS																		
32 Adoption marketing	Contractor																		
33 Radio collar testing	USGS																		
34 Shade study	UC Davis																		
35 WHB thermal environment	APHIS																		
36 Tubal ligation	U Ky.																		
37 Contraceptive peptides	LSU																		
38 Spay outcomes [5]	USGS																		
39 Public survey [5]	Ipsos PA																		
40 Spay testing [5]	Oregon SU																		
41 Minimally invasive sterilization [5]	Oregon SU																		

Legend

- *Fertility*
- *Modeling*
- *Genetics*
- *Safety*
- *Welfare*
- *Ecology*
- *Surveys*
- *Polling*
- *Human Dimensions*

[4] Captive trial funded by State of California. The project seeks to use BLM wild horses in a future field trial.

[5] These studies were never started, for litigation, logistical, or administrative reasons.

The following text highlights some projects that addressed the four major research topics identified in the 2005 WHB research strategy.

Health and Handling

The 2005 strategy suggested that the BLM should study actions that would maintain, protect and improve the health and well-being of wild horses and burros held in captivity. BLM supported a UC Davis study that examined wild horse tolerance for heat and use of shade structures at the BLM Palomino Valley Wild Horse Corrals. Under the observed conditions, the researchers found that horses made use of available shade, but that it was not required to protect their health (Holcomb and Stull 2016, Holcomb 2017). Based on this information, the BLM updated its shade and shelter requirements for WHB placed into private care, with protections that vary according to local weather patterns and legal requirements.

Fertility Control

The 2005 strategy identified the BLM's priority need for long-lasting contraceptive methods, preferably those that require only one handling event. The NAS identified three 'most promising' treatments, at the time of their 2013 report, as being PZP vaccines (ZonaStat-H, PZP-22, SpayVac), chemical vasectomy and the GonaCon vaccine, and encouraged the BLM to support development and testing of other methods as well. Testing new or improved long-lasting fertility control methods can require several years of research to determine safety and long-term effectiveness. A benefit of simultaneously funding research into many potential fertility control methods in 2015 was that promising methods were identified (e.g., Y-shaped silicone IUDs, GonaCon vaccine booster, oocyte growth factor vaccine) while studies of methods that failed (e.g., O-ring silicone IUDs, and a form of tubal ligation), and associated expenses, were stopped early.

BLM-funded studies monitored effects of PZP vaccines, particularly of pelleted PZP vaccine formulations such as PZP-22. In an initial field trial at Clan Alpine HMA, PZP-22 doses reliably conferred 2 years of contraception (Turner et al. 2007). However, the 'Annenburg study' at Cedar Mountains HMA and Sand Wash Basin HMA revealed that PZP-22 did not reliably produce 2 years of contraceptive effect, though it can lead to moderately high efficacy for 3 years after a subsequent PZP vaccine booster (Rutberg et al. 2017). Based on these results, the BLM now uses PZP-22 in mares in cases where PZP vaccine is to be used but where it is advantageous to not have to hold the mares in captivity for 30 days to receive a booster shot. A booster shot would be needed after just 30 days, for first-time use of ZonaStat-H. Since 2013, reports to BLM from University of Toledo and USGS research showed that neither PZP-22 pellets (Turner 2017) nor SpayVac as formulated at the time (Roelle 2015) caused reliable long-term contraception from one dose.

The BLM has focused on female contraception, because reducing female fertility most directly affects herd growth rates. In work on the Sheldon National Wildlife Refuge, funded by the US Fish and Wildlife Service, Collins and Kasbohm (2016) showed that mare sterilization did not prevent treated mares from consorting with other horses, did not reduce treated mares' on-range survival rates, and did reduce population growth rates in proportion to the fraction of mares treated. Scully et al. (2015) showed that chemical vasectomy was not effective at sterilizing stallions.

NAS (2013) suggested further research into behavioral and contraceptive effects of GonaCon vaccine. Such studies have since taken place in NPS- and BLM-funded studies at Theodore

Roosevelt National Park (Baker et al. 2013, Ransom et al. 2014, Baker et al. 2018). There were minimal behavioral effects, and a booster dose of GonaCon caused highly effective fertility control in mares (91% average effectiveness over 4+ years for animals treated with two hand-injected doses; Baker et al. report to BLM). Although the BLM will continue to use PZP vaccine, especially where darting of the PZP vaccine ZonaStat-H occurs and has shown to be successful, the BLM has been increasing its use of GonaCon.

Population Estimation and Modeling

Before 2013, most of the BLM's aerial surveys used 'raw count' methods that did not allow for a statistical estimation of how many animals were present in the survey area, but not seen. The 2005 strategy and the 2013 NAS reports acknowledged that 'raw count' surveys were likely underestimating the actual numbers of WHB on range. The BLM subsequently partnered with USGS to develop and test several aerial survey methods. Two have been validated in multiple areas: simultaneous double-observer (Lubow and Ransom 2016), and photo mark-resight (Lubow and Ransom 2009). The simultaneous double-observer method has become the standard method for wild horse and burro aerial survey data collection (Griffin et al. 2020) and analysis (Ekernas 2019). Infrared aerial surveys have also been validated in at least one area with limited vegetation (Schoenecker et al. 2018).

The 2005 strategy called for an update to the 1996 WinEquus horse population projection model, and USGS is currently developing a user-friendly population and cost projection model, "PopEquus."

Genetics

The BLM has a long-term commitment to genetic monitoring, and has sent over 200 sets of samples from monitored herds for laboratory analysis. Results regularly inform the BLM's management decisions at local levels. The 2005 strategy noted the importance of determining the genetic population structure of WHB across the west, including identifying genetically connected subpopulations ("metapopulations"). The small size of some subpopulations may not be a grave concern with respect to genetic diversity, because they are generally part of a larger connected metapopulation in which historic and present gene flow maintains genetic diversity. Patterns in microsatellite DNA allelic diversity were the basis for an analysis of WHB genetic diversity in the NAS report (2013), which found only three herds with notably high Spanish influence (in Pryor Mountains, Sulphur, and Cerbat HMAs). The same report showed that most BLM-managed wild horse herds are highly related, in terms of Fst values, which are a measure of subpopulations' differentiation. Most recently, an analysis of wild horse genetic samples confirms that most herds are part of a single, large, genetically-connected metapopulation (Cothran et al., Texas A&M University, in review).

Table of Past and Present Wild Horse and Burro Research and Related Projects

Research Entity; Project Name	Dates[6]; Budget	Description and Status	Management Applications
BLM-funded or facilitated WHB research and related projects			
1. USDA - APHIS - National Wildlife Research Center; Evaluation of a vaccine against ovarian growth factors as a single dose, long-lasting immunocontraceptive	2019-2022; $238,281	Goal: Pen trial building on project #5, test whether a one-dose version of the vaccine against BMP-15 and GDF-9 causes long-term infertility. Status: Ongoing. BLM's final Environmental Assessment (March 2020) describes the ongoing study at Northern Nevada Correctional Center. 16 mares were injected with vaccines and 16 with placebos, in May 2020. In theory, the mare may deplete her ovaries of fertile oocytes, thus becoming sterile. Stallions were introduced to mare groups in August 2020. Antibody levels and foaling rates are currently being recorded for treated and untreated mares.	If successful, this one-shot vaccine would permanently sterilize mares, and no further treatments for the life of those animals would be needed.
2. USGS; Evaluating behavior and ecology of geldings among a breeding population	2015–2020; $826,099[7]	Goal: Use a field trial to determine the behavioral and demographic effects of having a portion of a herd be gelded male (neutered) wild horses. Status: Data collection complete. Gather took place at Conger HMA in fall 2016. 30 mares were fitted with radio collars. 29 studs were fitted with radio tags, but 13 of 14 GPS tail tags had firmware issues and were re-deployed in spring 2017. Further collars and tags were deployed after the treatment gather. Aerial surveys were conducted every spring 2017-2020. As part of a gather in which family groups and bachelor stallions were captured together, held, and released together, 27 studs were gelded in a facility in December 2017. All horses were returned to the range shortly thereafter, including treated and non-treated bachelor stallions and social groups with treated stallions and untreated control stallions. 2018-2020 were the three post-treatment years of the study. Gelded stallions maintained harems in 2018 similar to ungelded, and displayed similar reproductive behaviors as intact stallions. The foaling rate post-treatment appears lower for only one year, compared to pre-treatment.	Field offices may be more confident about using gelding because of this study. Geldings can temporarily reduce herd growth rates if they take the place of mares, or if they continue to defend harems.

[6] Dates listed are for planned data collection and publications. Unless otherwise noted, the budget listed includes obligated BLM funding.
[7] Costs of aerial surveys are not included in USGS project budgets. Those aerial surveys will be led and paid for directly by BLM.

Research Entity; Project Name	Dates[6]; Budget	Description and Status	Management Applications
BLM-funded or facilitated WHB research and related projects			
3. USGS; Evaluating the efficacy and safety of Silicone intrauterine devices as a horse contraceptive	2016–2020; $750,826	Goal: Pen trial of the efficacy and effects on mare health resulting from the long-term presence of a silicone intrauterine device (IUD). Status: Complete. From 2017 to 2019, 75% or more of flexible, 'Y' shaped silicone IUDs stayed in mares that got an injection of progesterone at the time of IUD insertion. After removal in March 2019, most mares (12 of 19) returned to fertility the first season after removal of IUDs and IUDs provided 100% contraception while in place. IUDs did not significantly change the endometrial biopsy scores on any mares (no significant harm to their uterus as revealed by biopsy scores; Holyoak et al. 2021 in press). The IUD tested in this study is now made by an EPA-registered manufacturer, and is available for BLM's use.	This study has given BLM another low-cost, long-lasting fertility control tool. IUDs can go into open (non-pregnant) mares that would be released to the range, reducing holding costs and future foal births.
4. USGS; Development of a population model and cost analysis for managing wild horses (also known as "PopEquus")	2016–2022; $459,859	Goal: Update the existing WinEquus model used by managers for wild horse population projections. The new software will compare population outcomes and economic costs resulting from PZP, removals, mare sterilization, gelding and other population growth suppression tools. Status: Model in preparation. BLM staff tested simple model in late February 2019. Preliminary model results were shown in conferences and meetings in 2018 and 2019. USGS aims to beta test in spring 2021.	When fully implemented, the model can assist managers in comparing costs of gathers and different kinds of fertility control.
5. Colorado State University; Effect of Immunization against Oocyte Specific Growth Factors in Mares	2015–2020; $1,110,065	Goal: Initial vaccine development to test whether vaccines against two ovarian proteins (BMP-15 and GDF-9) in domestic mares cause infertility. Long-term goal is to develop a vaccine that can cause permanent sterility from one dose. Status: Data collection complete. In 2017, a 4-dose vaccination against each protein individually led to irregular follicle development, and one of the vaccines reduced ovulations. Ten mares had 4 doses of a combined vaccine with both proteins. None of those mares ovulated in 2018, (only one in 2019); follicles developed only to a very early and small stage; progesterone levels remained low (Davis et al. 2018). These promising results led to study #1 (above, in this table).	This study showed that this new type of fertility control vaccine could, in theory, sterilize mares. The four-shot version of the vaccine worked well, but now is being tested as a one-shot vaccine, in project #1.

Research Entity; Project Name	Dates[6]; Budget	Description and Status	Management Applications
BLM-funded or facilitated WHB research and related projects			
6. Colorado State University; Re-immunization of Free-Ranging Horses with GonaCon Vaccine	2015–2020; $287,884 (*and with in-kind support from National Park Service*)	Goal: Field trial at Theodore Roosevelt NP to determine the optimum booster schedule; duration of effectiveness; and safety and physiological side-effects (if any) following booster vaccination with GonaCon. Status: Data collection complete. A single GonaCon booster dose causes 4 or more years of infertility, when injected by hand. Field crews observed foaling rates in 2016-2019, and will continue in 2020. Untreated mares foaled at high rates of 75-100%. The foaling rate for mares re-treated with GonaCon 4 years after initial dose were 0%, 16%, 4%, 8%, 8%, and 21% in 2015-2020. For mares boostered by dart 2 years, 1 year, or 6 months after their primer dose, the 2018-2020 foaling rates were 18%, 34%, and 37%. The researchers published early results (Baker et al. 2018), and are preparing article(s) on dart-based delivery and efficacy results.	Using this vaccine repeatedly would slow annual population growth rates and could allow for longer times between gathers. BLM is now including GonaCon in many NEPA analyses and has begun to use it more in management. SOPs for GonaCon use are available.
7. Humane Society of the United States; Applicability and efficacy of ZonaStat-H on wild burros in northwestern Arizona	2016–2021; $64,975 *(Humane Society of the USA matched $350K*)	Goal: Field trial to test whether ZonaStat-H (a PZP vaccine) can be effectively darted to wild burros in the vicinity of Oatman, Arizona. Status: Ongoing. Trapping, marking, and initial treatments for 108 jennies are completed. HSUS continues to deliver booster doses via dart to those jennies that only received a primer dose (with good success to date), and to monitor time and effort required, apparent foaling rates and any apparent injection site responses. Some burros had abscesses at injection sites and transient lameness, which resolved. In one study group, HSUS boostered 2/3 of jennies by dart, though that took up to six months, while optimal timing is one month.	This information could be included in NEPA analyses when local offices are weighing the costs and benefits of dart-based vaccine delivery in large HMAs.

BLM-funded or facilitated WHB research and related projects			
8. Ohio State University; Electrospun delivery to enhance the effectiveness of immunocontraception strategies in equids	2016–2020; $799,565	Goal: Develop and test polymer capsules that would be a new delivery vehicle for porcine zona pellucida (PZP) vaccine, to increase the duration of vaccine effectiveness. The vaccine is in liquid form, inside the capsules. Status: Data collection complete. The researchers tested capsules made from various surgical grade polymers, to determine optimal thickness of implantable capsules. One-month hydrophilic silicone oil + PZP emulsion, and 3-month, 12-month and 12+ month capsules were implanted in domestic mares in summer 2017. The 1-month emulsion and 3-month capsule seem to have delivered the PZP, approximately on schedule. Those delivery methods led to higher antibody titer levels than the PZP-22 treatment. Only a very small antibody titer peak was caused by the 12-month or 12+ month capsules. Different PZP batches led to different antibody titer responses. Despite several materials science papers published (Chaparro et al. 2019a, 2019b) and in preparation, no breakthrough reductions in wild horse fertility rates are expected from this work. Use of the silicone oil could provide a 1-month booster PZP dose without holding animals.	If the 12-month capsules worked well, they could deliver a 1-year booster dose, which would save thousands of dollars in capture costs per mare. Results are not yet a breakthough new method.
9. Purdue University; Development of next-generation anti-fertility vaccines for horses	2016-2019; $78,375 BLM (*$375K matching from HSUS*)	Goal: Develop and test new PZP-type vaccines for use in mares, making use of a water-soluble adjuvant, and recombinant ZP proteins. An effective water-soluble vaccine could be an improvement over ZonaStat-H PZP vaccine, which requires laborious mixing and does not store well. Status: Complete. Experiment 1 identified promising new adjuvant combinations for vaccine, based on in vitro testing. Experiment 2 tested the antibody response of mares injected with rZP and the new adjuvant, starting in late spring 2017; antibody titer response levels were not as high as predicted, though it is not always clear how titer levels relate to fertility. In experiment 3, two doses of the water soluble 'combination adjuvant,' comprised of two immune-stimulating molecules (poly(I:C), and CpG) and of nanoparticles (Nano-11) that adsorbed a model antigen (ovalbumin), led to a stronger immune response than treatment with the model antigen alone, or the antigen and the Nano-11. The systems for rZP3 and rZP2 protein work; production of rZP4 in progress. In 2019, they intended to use mice to test a new vaccine with rZP2, rZP3 and the 'combination adjuvant.'	PZP vaccines made from pig ovaries could be banned if swine fever gets into the US pig population. Having a recombinant ZP vaccine as a backup may be needed.

BLM-funded or facilitated WHB research and related projects			
10. BLM; GonaCon Vaccine Pilot Project	2015-2025	Goal: BLM pilot project to stabilize the number of wild horses in the Water Canyon area of the HMA at 25-30 animals. Captured wild mares from the Water Canyon area of the Antelope HMA were treated with an initial dose of the GonaCon-Equine immunocontraceptive vaccine in 2015, held in captivity 30 days, given a booster dose of GonaCon, then released. Status: Monitoring by BLM staff is ongoing. 15 mares were gathered, marked, treated, boostered, and released. 10 of those and 2 new mares were treated in 2017. 10 previously-treated mares received boosters in 2019.	This project has shown that repeated BLM use of GonaCon vaccine drastically reduces wild horse birth rates.
11. Texas A&M University; BLM Wild Horse and Burro genetic monitoring	2015–2020; $98,000 2020-2025; Up to $182,625 in 5-year contract	Goal: Analyze genetic diversity for wild horse and burro populations, based on hair samples taken during capture operations. Status: Ongoing. This study provides monitoring information to BLM that is useful for management. BLM sends hair samples to the researcher. The researcher then provides genetic monitoring reports to BLM. The researcher has submitted a paper on metapopulation structure (genetic connections between sampled herds; Cothran et al., In review). Current genetic monitoring work is via contract with the same lab.	BLM relies on genetic monitoring to counter any claims that BLM management is causing unacceptable inbreeding or loss of genetic diversity.
12. UC Davis School of Veterinary Medicine; Minimally invasive mare sterilization	2020[8]; $0 *No BLM funding yet*. $160,000 *funded by California Legislature*	Goal: First, develop veterinarians' skills in a minimally invasive sterilization method, where mare oviducts are blocked by a transcervical approach. Status: Ongoing early trials. A pilot study with 6 mares showed infertility for more than 3 years, and anatomical signs of sterility. The California legislature funded phase 1 of the project, for veterinary training with domestic horses. Researchers have demonstrated success in domestic burros, and intend to soon conduct trials in domestic horses. Phase 2 may include a field trial of the method with BLM wild horses.	This is a minimally-invasive sterilization method. There may be a relatively higher level of public support among some wild horse activists, compared to surgical removal of ovaries.

[8] **This study is not yet BLM-funded or approved, but California passed a law funding a proposal that seeks BLM's involvement in testing this method in the near future**.

BLM-funded or facilitated WHB research and related projects			
13. University of Toledo; Development of a 3-4 year controlled release PZP contraceptive vaccine for wild horses	2010-2017; $2,165,000	Goal: The project supported development of a 3-year or 4-year PZP pellet vaccine, testing that PZP-22 vaccine pellets caused 2 years of contraception, and PZP-22 production costs, for management use. Status: Complete. The work builds on earlier studies (Turner et al. 2007, 2008). A captive trial at the Carson City prison facility showed that PZP-22 was not providing even the second year of contraception that was expected. PZP-22 pellets provided only 1 year of contraception, and at a fairly low rate – but *are* convenient for providing the PZP booster dose without needing to re-capture or dart a horse. The vaccine pellets that had been intended to work for 3-4 years simply did not. The PZP-release profile of a new design of 12-month pellets, in vitro showed that those pellets degraded by month 10, over the course of 3-4 weeks. BLM now procures PZP-22 vaccine pellets through a contract with U. of Toledo. Though there have been several papers about use of PZP-22 (most recently, Rutberg et al. 2017, Carey et al. 2019), negative results from the Carson City trial have not been published.	This project showed that PZP-22 vaccine pellets are not as effective as had been expected. Much of the cost of the project was to pay for PZP-22
14. University of Toledo. (PZP-22)	2005-2010	Goal: Develop and test polymer pellet-based PZP vaccine, with long-lasting effects, now known as "PZP-22." Status: Complete. The pelleted form, PZP-22 vaccine, is helpful for management. Mares can be treated with one liquid dose and one set of PZP pellets, without the need for the mares to be held 30 days to get a booster dose. Early results suggested that this form of PZP vaccine may be effective for 22 months, though that duration has not been consistently replicated in later results. (Turner et al. 2007, 2008)	PZP-22 has the benefit of not requiring mares to be held for 30 days to get a booster dose. BLM still uses this formulation of PZP vaccine
15. Humane Society of the US, PZP field trials (the 'Annenburg Study')	2008-2013, *(jointly funded by HSUS)*	Goal: Test the efficacy of PZP-22 pellet vaccine in free-roaming wild horse herds. Status: Complete. Field work at Sand Wash Basin HMA and Cedar Mountain HMA included initial treatment with PZP-22, which led to relatively low efficacy 2 years after treatment. Following booster treatment with PZP-22 or a liquid PZP vaccine, up to 3 years of moderate efficacy followed (Rutberg et al. 2017).	PZP-22 vaccine pellets require a booster dose to cause moderate fertility control reduction for 3 years.

BLM-funded or facilitated WHB research and related projects			
16. USGS; Pen trials of the SpayVac PZP vaccine	2011–2015; $127,379 (2nd trial)	Goal: Conduct two trials of SpayVac, to test for long-lasting effects. SpayVac is a PZP-based immunocontraceptive with liposome technology. Status: Complete. The initial trial from 2011-2014 led to fertility rates of 13%, 47%, and 13 % in three years, respectively, after treatment with an aqueous emulsion formulation. The nonaqueous formulation led to poor fertility control and that portion of the study was discontinued. Results stemming from the 2012-2014 trial were published (Mask 2015, Roelle et al. 2017, Bechert et al. 2018b). In 2014, a second pen trial ("SpayVac II") aimed to identify optimal adjuvant formulation for the aqueous formulation. However, that second trial was discontinued in spring 2015, after results indicated that both forms of the aqueous SpayVac formulation did not substantially reduce fertility in treated mares (53% and 70% pregnant in two treated groups, compared to 83% in untreated mares). Negative results from the second trial (Roelle 2015) have not yet been published. Injection site has been hypothesized to play a role (Bechert et al. 2018a).	Earlier studies showed promising results from a formulation of SpayVac vaccine, but the SpayVac vaccine had unexplained, poor results in a follow-up trial.
17. USGS; Studies of demography, behavior, ecology, and immunocontraception and wild horses	2001-2014; **$0** (*funded by USGS, other than gathers and survey flights*)	Goal: Characterize safety and effectiveness of PZP and GonaCon vaccines; summarize wild horse demographic information; characterize behaviors; describe ecological effects of wild horses as a function of density. Status: Complete. PZP effectiveness and immune site reactions were quantified (Roelle and Ransom 2009, Ransom et al. 2011). Wild horse demography was summarized (Roelle et al. 2010, Ransom et al 2016). Studies of wild horse behavior (Ransom 2009) included effects of GonaCon vaccine (Ransom et al. 2014). Population models showed that female sterilization poses few risks to most wild horse herds' viability (Roelle and Oyler McCance 2015). Wild horse grazing ecology was described (Ziegenfuss et al. 2014, Schoenecker et al. 2016).	Many papers from these studies are important references for WHB management decisions.
18. USGS (Western Ecological Research Center)**;** Stressors to Greater Sage-grouse	2016-2021; $280,000 (Funded by NOC)	Goal: Study Sage-grouse populations to determine effects of non-native grasses, wildfire patterns, wild horse and livestock grazing, and land uses. Status: Ongoing. Observational work indicates that wild horse presence may reduce sage grouse numbers at lek sites (Muñoz et al. 2020). A forthcoming paper provides evidence that wild horse herds above AML have negative effects on Sage-grouse population growth rates (Coates et al. In press)	The result that wild horse herds over AML have direct negative effects on Sage-grouse populations underscores the importance of bringing herd levels down, in Sage-grouse habitats.

BLM-funded or facilitated WHB research and related projects			
19. USGS; Effects of wild horses and livestock on sagebrush ecosystems	2019-2021; $381,060 *from BLM Nevada, and $357K from USGS)*	Goal: This is primarily a Sage-grouse study; no BLM WHB funds are earmarked for this work. The goal is to study effects of wild horses and livestock on sage grouse reproduction, survival and habitat structure in several areas of Nevada. Status: Ongoing. USGS has worked with BLM Nevada to study livestock and sage grouse in several areas. In winter 2019, BLM conducted a gather in Desatoya HMA, and USGS deployed GPS tail tags on a small number of fertility control-treated horses that were turned back to the range, to study their movements.	This study would inform land-management decisions where wild horses overlap with Sage-grouse.
20. USGS; Population demography and ecology of wild horses in two sentinel herds in the western United States	2015–2022; $1,287,654[3]	Goal: Study survival, fertility, fecundity, and recruitment rates; movement patterns; range use; habitat selection; and social behavior of wild horses. Status: Ongoing. About 95 horses were captured at Frisco HMA via a helicopter gather in summer 2016, with more captured in January 2017. Horses were fitted with radio collars or radio tags, then released. Observations began after radio marking and are ongoing through 2019. Aerial surveys took place in spring 2017, 2018, and 2019. The untreated portion of the Warm Springs HMA, where a cancelled spay study was intended to occur, was proposed to have been the second sentinel demography herd site; next steps for the second site are uncertain at present.	Population models for cost-benefit analyses rely on accurate demographic rates – such as from this wild horse study.
21. USGS; Demography of two wild burro populations in the western USA	2015–2020; $717,081[3]	Goal: Study survival, fertility, fecundity, and recruitment rates; movement patterns; range use; habitat selection; and social behavior of wild burros. Status: Data collection complete. At Sinbad HMA, 30 burro jennies were returned to the range with GPS radio collars in 2016. Field work to monitor their welfare, movements, behavior, survival, and foaling took place May-September in 2016 and March-September 2017, 2018, and 2019, with monthly welfare checks in winter. The most recent aerial survey at Sinbad HMA took place in October 2018. At Lake Pleasant HMA, trapping and collaring began in December 2016 and was completed in July 2018. 30 jennies got USGS collars, and another 26 got AGFD collars (see AGFD project, above). Observations are ongoing through 2020 at Lake Pleasant. An aerial survey took place at Lake Pleasant HMA in June 2017.	Population models for cost-benefit analyses rely on accurate demographic rates – such as from this wild burro study

BLM-funded or facilitated WHB research and related projects			
22. University of Wyoming; Adobe Town HMA Wild Horse GPS Collar Study	2016-2020; $40,000 (*$120K matching from WY Dept. of Ag.*)	Goal: Assess habitat use, and movement in / out of checkerboard lands, and potentially across state lines, in Adobe Town HMA, Wyoming. Status: Data collection complete. 14 mares were fitted with radio collars after bait trapping in early 2017, and 23 radio collars were placed on mares in October 2017 in conjunction with a helicopter-gather in the HMA. Collars dropped off in October 2019. Results will contrast horse habitat use with habitat use by pronghorn antelope and Greater sage-grouse in the same region, based on GPS collars and tags on those other species. (Hennig et al. 2018, Hennig et al. 2020a).	This study has mostly local applications, showing how horses move across 'checkerboard' ownership in a large HMA. Understanding local movements may help in future gathers and rangeland impacts.
23. Arizona Game and Fish Department; Evaluation of burro movements and collisions along roads near Lake Pleasant HMA	2016-2021; **$0** from BLM to AGFD, but BLM did fund capture costs (*~$200K AZ DOT. funding*)	Goal: Use GPS collars on wild burro females (jennies), to determine movement patterns near roads, identify key crossing points, and infer what types of highway fencing could help to prevent burro-vehicle collisions. Status: Data collection complete. Trapping near the Lake Pleasant HMA took place February 2017 - July 2018. 26 burros were collared. Up through early 2019, two died in vehicle collisions and four others died for unknown reasons that may have been related to drought. The study identified geographic areas and specific roadside features to improve, to reduce burro vehicle collisions (Gagnon et al. 2018). For example, they found that 4-strand barbed wire works well if it is maintained, with no breaks or gaps.	ADOT funded the researchers, and BLM funded the captures. Because of these results, ADOT has started to change roadside fencing in this area – this has likely reduced the number of burro collisions.
24. USGS; Testing the Accuracy of High-definition Infrared Imaging for Wild Horse Aerial Surveys	2015–2016; **$0** (*funded by Wyoming Dept. of Agriculture*)	Goal: Test the use of distance-based analysis along with infrared aerial surveys, in an area with known horse population size. Status: Complete. Two infrared aerial surveys were conducted at the McCullough Peaks HMA: in fall 2015 in the daytime and at night in summer 2016. Estimated population sizes from that survey were close to known population sizes, due to high detection rates. However, the distance analysis method was unable to determine what fraction of animals were missed. Costs are higher than typical surveys, and the method may not work in areas with more tree cover. (Schoenecker et al. 2018).	An infrared camera, mounted under a manned airplane, can lead to accurate herd size estimates in open habitat types.

BLM-funded or facilitated WHB research and related projects			
25. USGS; Developing and testing aerial survey techniques for wild burros	2015–2019; $185,139[3]	Goal: Test two new population survey methods for wild burros: use of infrared cameras; and using information from radio collared burros in double-observer surveys. Status: Data collection complete. In Sinbad HMA, USGS and BLM completed 3 infrared surveys and have conducted 5 double observer surveys, 4 using the radio collared animals. A fall 2017 survey at Lake Pleasant HMA collected data using radio collared animals. In 2016 and 2017 USGS and BLM helped with burro aerial surveys at Fort Irwin NTC (Dept. of Defense), which will contribute data to the double-observer sightability modeling. One more survey (at Lake Pleasant) is planned for FY2020, with data analysis using the full data set to follow.	Burros are often undercounted even more than horses. Accurate and repeatable population surveys are vital to inform BLM managers of herd size status and to evaluate management action outcomes.
26. USGS; Non-invasive (fecal) genetic sampling of free-roaming horses to estimate population size, genetic diversity, and consumption of invasive species	2014–2015; $178,538	Goal: Collect and analyze fecal DNA as a noninvasive method to determine genetic diversity and estimate population size. Also, test for presence of invasive species, and seed germination. Status: Complete. Feces collection and analysis concluded in 2015. This seems to be a suitable method for population estimation in small areas, though the costs are currently high. USGS has published manuscripts: on environmental degradation of horse fecal DNA (King et al. 2018. Ecology and Evolution); on diet analysis (King and Schoenecker 2019 Rangeland Ecology and Management); on cheatgrass in feces (King et al 2019); and on using mark-recapture techniques to estimate population size (Schoenecker et al, In press).	This study demonstrated that BLM could use DNA from horse dung to estimate herd sizes, and measures of genetic diversity. However, as of today it costs several times more than aerial surveys, and only works well in small herds.
27. USGS; Development and testing of new aerial survey methods for wild horses	2001-2014; **$0** (*funded by USGS, other than BLM flight costs*)	Goal: Develop and test new aerial survey methods for wild horses. Status: Complete. The 'simultaneous double-observer' and the 'photo mark-resight' aerial survey methods were validated by successful comparing estimated herd sizes and known herd sizes (Lubow and Ransom 2009, Ransom 2012, Lubow and Ransom 2016, Ekernas 2019, Griffin et al. 2020)	BLM has adopted recommendations of NAS (2013), and now largely uses double-observer SOPs for flights.

BLM-funded or facilitated WHB research and related projects			
28. WEST, Inc.; Testing double-observer plus distance methods for aerial surveys	2016; **$0** (*funded by Wyoming Dept. of Agriculture*)	Goal: Tested a distance-based aerial survey method, similar to those now used by BLM ("double-observer" method), but is based on an incomplete sample of the surveyed areas. Status: Complete. The contractor completed aerial surveys over areas including the North Lander complex and Red Desert complex in 2016. In a final report sent December 2016, the contractor's method estimated lower horse abundance for the North Lander complex than was counted visually by BLM staff on a 2016 helicopter survey in the same area. The researchers used the same method to estimate feral horse abundance on Navajo Nation lands in 2017 (Wallace et al. 2017, 2020).	This aerial survey method led to confidence intervals that were not nearly precise enough for BLM management needs.
29. BLM; Census of wild horse populations via remote sensing analysis	2018-2019; $0 (*staff time supported by BLM Wyoming*)	Goal: Pilot project that will attempt to use image classification technology to determine whether or not an algorithm can developed to accurately identify horses from available satellite or other aerial imagery. A BLM Wyoming employee conducted the project as part of her masters degree program in GIS, through Kent State University. Status: Complete. Wild horses were not visible often enough in satellite imagery to be used in the pilot study. The resolution of the imagery used (~18 inch pixels) was also not good enough to reliably identify cows.	For now, available free satellite imagery is too coarse to use for counting wild horses.
30. University of Idaho; Focus on Impact of Wild Horses on Riparian Areas	2014–2015; $19,999	Goal: Use wildlife cameras to record use of riparian areas by wild horses, livestock, and wildlife, and vegetation measures in those areas. Status: Complete. Wild horses influenced riparian streambank conditions and herbaceous stubble height to a greater degree than livestock, which also had an effect. The study found no statistical relationship between wild horse presence and wildlife presence. Published results showed that per-horse impacts on riparian disturbance, vegetation height, and biomass were greater than per-cow impacts (Kaweck et al. 2018).	This project confirmed that wild horses can have greater per-capita ecological impacts on riparian areas than cattle.
31. USGS; Modeling Carrying capacity of free-roaming horses (with Colorado State University cooperation)	2014–2017; **$0** (*funded by USGS*)	Goal: Develop a coarse model to evaluate changes in animal carrying capacity in response to changes in vegetation production. Status: Suspended. USGS received data from various sources. The carrying capacity model was developed at Colorado State University. After final input using range health data to ground truth the statistical model, CSU is revising its analysis in light of feedback from BLM received February 2017.	Carrying capacity models can overestimate forage capacity if they rely on outdated or inaccurate information.

BLM-funded or facilitated WHB research and related projects			
32. Great Lakes Marketing Research; Analysis and evaluation of demand for off-range WHB	2015–2016; $109,300	Goal: Assess demand for wild horses and burros through adoption and sales and to develop strategies for placing more animals into private care. Status: Complete. The contractor prepared analyses, presented final reports to the BLM, and led webinars on the implications.	BLM has taken recommendations from this study into account, for marketing, adoption, sales, and event planning.
33. USGS; Developing a suitable radio collar or radio tag for feral horses and burros	2014–2016; $139,248	Goal: Develop and test four radio collar designs and two designs for mane and tail radio tags. Assess behavior and monitor for any injuries caused. Status: Complete. Fieldwork in captivity was completed March 2016. No substantial injuries were observed in mares, stallions, or jennies. Collars went over the ear of several stallions, so USGS recommended against their use on stallions. Further field testing is ongoing. Collared mares are checked once per month, to ensure there are no negative effects. Collars that slipped up over mares' ears have been dropped off remotely or otherwise removed. (Schoenecker et al. 2020, Hennig et al. 2020b).	This project ensured that other studies could happen without the risks of injuring horses. This study showed risks to stallions, so BLM does not now use radio collars on stallions.
34. UC Davis; Wild Horse and Burro Shade Study	2014-2015; $48,472	Goal: Determine whether shade is necessary for captive horse health, at BLM's Palomino Valley Center WHB corrals. Status: Complete. In the range of observed temperatures, horses used shade for comfort, but it was not a requirement for animal health. (Holcomb and Stull 2016, Holcomb 2017)	Results of this study helped to inform 2015 revisions to BLM's private care shelter requirements.
35. USDA APHIS; Evaluation of Mustang and Burro Thermal Environment at PVC	2014-2015; **$0** (*~$3,000 paid by USDA APHIS*)	Goal: Clinical evaluation of whether shade is necessary for captive horse health, based on measurements at Palomino Valley Center. Status: Complete. The researchers used thermal imaging to determine heat balance in horses and burros at the corrals. In the range of observe temperatures, so long as healthy animals have adequate water, no shade structures are needed.	Results of this study helped to inform 2015 revisions to BLM's private care shelter requirements.
36. University of Kentucky; Tubo-ovarian ligation via colpotomy as a method for sterilization in mares	2015–2017; $120,228 spent pre-closeout. *Original budget $391,369*	Goal: This project ended early. The project aimed to help determine the effectiveness of placing a polyamide (nylon) cable tie around the ovarian pedicle and oviduct of mares via colpotomy for tubo-ovarian ligation. Status: Discontinued. Initial trials showed that the new instrument was effective for ligature placement. Several mares in the study, however, developed adhesions near the ovaries that caused concern. The project ended 1/31/2017, and remaining funds (~$271K) were deobligated in early FY2017.	Negative results from the project led to its early ending. The specific surgical method has been ruled out.

BLM-funded or facilitated WHB research and related projects			
37. Louisiana State University; The use of membrane disrupting peptide / peptoid LHRH conjugates to control WH&B populations	2016–2018; $295,992 spent pre-closeout. *Original budget $850,002*	Goal: Develop and test an injectable protein to decrease female and male gonad viability. The drug would destroy the cells that control spermatogenesis in the male and follicle growth, oocyte development, ovulation and cyclicity in the female. Status: Discontinuted. Due to negative results, this project was closed out, and the remaining funds (~$554K) were deobligated in early FY2019. The research group identified peptide conjugates that were most effective at targeting LHRH receptor cells *in vitro*, while at the same time not destroying blood cells. Even at very high daily doses, the ponies did not cease to ovulate.	Negative results from the project led to its early ending. The method has been ruled out.
38. USGS; Monitoring responses of wild horse behavior and demography to BLM management treatment *(mare sterilization;* cancelled*)*	2019; ~$800 spent on pre-work	Goal: This project would have determined the behavioral and demographic effects of having a portion of sterilized mares in a wild horse population. BLM would conduct the treatments with a veterinary contractor. USGS involvement would be limited to studies of on-range outcomes, after treatment. Status: Cancelled before the study began. The project as outlined in 2018 was suspended. An earlier proposal included Colorado State University, but following intense public pressure, that university chose to remove itself from the research. A revised USGS research proposal was approved by BLM, and a Decision Record was signed on September 12, 2018. However, litigation regarding NEPA adequacy and public viewing forced BLM to rescind that decision and withdraw the project from consideration at that location.	This would have been BLM's first use of surgical mare sterilization. Whether surgical or through some other means, sterilizing mares would reduce growth rates more than any temporary treatment. The study was cancelled.
39. Ipsos Public Affairs; Assessing knowledge, attitudes, preferences, and non-market values regarding WH&B populations and management (cancelled)	2014; $0 Spent	Goal: Improve understanding of public perceptions, values, and preferences regarding the management of wild horses and burros on public rangelands. At the time, there was no polling data that measures public opinion about WHB issues, based on a statistically sound sampling design. Status: Cancelled. BLM sought but did not get approval from the Office of Management and Budget (which oversees Privacy Act concerns) to conduct focus groups. A Utah State University study has, since then, conducted nationwide polling (see "Other WHB-related projects funded entirely by BLM partners or other sources," below)	No management applications; the project was never started.

BLM-funded or facilitated WHB research and related projects			
40. Oregon State University; Functional assessment of ovariectomy (spaying) via colpotomy in wild mares (cancelled)	2015–2016; $8,834 spent pre-closeout. *Original budget $42,063*	Goal: Researchers would have determined whether ovariectomy via colpotomy can be safely and effectively performed on pregnant and non-pregnant wild horse mares. Status: Cancelled before the study began. Although the project was approved and some spending occurred, this project never started; it was cancelled. Public pressure on the university partner, and particulars of litigation, led to BLM withdrawing its decision to support this research project on September 9, 2016.	No management applications; the project was never started.
41. Oregon State University; Evaluation of minimally invasive methods of contraception in WH&B mares (cancelled)	2015–2016; $498 spent pre-closeout. *Original budget $315,189*	Goal: The project would have evaluated two procedures, tubal ligation and hysteroscopically-guided laser ablation of the oviduct papilla in standing sedated mares. Status: Cancelled before the study began. Although the project was approved and some spending occurred, this project never started; it was cancelled. Public pressure on the university partner, and particulars of litigation, led to BLM withdrawing its decision to support this research project on September 9, 2016.	No management applications; the project was never started.
Other WHB-related projects funded entirely by BLM partners or other sources			
Utah State University	2020-2021 *(not BLM-funded)*	Goal: Conduct national polling about public attitudes toward WHB management. Status: Ongoing. 3,000+ individuals were polled on topics related to management, costs, and public attitudes. Results were presented at the 2020 FREES conference, and publication is in preparation.	Sound data on public opinions may be informative for management, and useful for messaging and outreach.
University of Massachusetts	Ongoing *(not BLM-funded)*	Goal: Test the safety and efficacy of a flexible, plastic-coated, magnetic IUD. Status: Ongoing. Pen trials have demonstrated that the iUpod prevents pregnancy and prolongs the time between estrus cycles (Gradil et al. 2019, Joonè et al. 2021). Ongoing field work aims to test whether free-roaming IUD-treated mares are contracepted, in the company of fertile stallions.	This design of IUD may be another useful tool in contraception.
National Park Service, Colorado State University, and USGS	2009-2015; $0 (*funded by National Park Service*)	Goal: Test the efficacy and behavioral effects of GonaCon vaccine on feral horses in Theodore Roosevelt NP. Status: Complete. NPS supported this initial work, which confirmed that a single dose of GonaCon vaccine can cause moderate reductions in mare fertility. Behaviorally, GonaCon-treated mares were comparable in some ways to pregnant mares. (Baker et al. 2013, Ransom et al. 2014b)	If only one dose is used GonaCon vaccine is only moderately effective to reduce mare fertility.

Other WHB-related projects funded entirely by BLM partners or other sources			
Wildlife Protection Management, Inc.	Ongoing *(funded by NM Small Business Assistance / Sandia Labs)*	Goal: Develop a bait station to remotely deliver contraceptive vaccine darts. Status: Ongoing. The company has a patented prototype for remotely triggered vaccine darting at a feed bait station. The system can read identification chips. Dart delivery is to the pectoral muscles. Facial recognition software may identify individual horses. Ongoing tests of private, free-ranging (not federally protected) horses.	The invention could deliver fertility control vaccines to wild horses at bait stations. It has not yet been used in the wild.
US Navy; Testing the accuracy of horse and burro surveys, using a drone-mounted infrared camera	2016; $0 (*funded by Department of Defense*)	Goal: Test the use of infrared and visual spectrum cameras mounted on a military Tiger Shark Unmanned Aerial Vehicle (UAV), to survey horses and burros at Centennial HMA (China Lake Naval Weapons Station). Status: Complete. Over flights in December 2016, the sensor package on the drone did not perform well when panned out at a wide angle. This was not suitable for surveying large areas. Future flights could be improved by a sensor system with a more sensitive infrared camera.	Unmanned drones would need high quality sensors if they will be used in wild horse and burro surveys.
University of Alaska, Fairbanks; Indigenous peoples and the horse	2013-2017 *(not BLM-funded)*	Goal: Document Native American oral histories and indigenous knowledge about horses in North America, and contrast with western scientific views. Status: Dissertation defended in 2017 (Running Horse Collin 2017)	Indigenous knowledge about wild horses may be an important human dimension, including in BLM and tribal management.
University of California Agricultural Extension	Ongoing *(funded by USFS)*	Goal: Use camera-traps to document interactions between wildlife, livestock, and wild horses, on the Modoc plateau. Status: Ongoing. Photo analysis is ongoing; no publications yet. This study is documenting use and habitat quality at water sources.	The study is documenting wild horses competing with wildlife and livestock.
Brigham Young University / US Army Dugway Proving Grounds	Multi-year *(funded by DoD)*	Goal: Use camera-traps to monitoring springs on the Dugway proving grounds, southeast of Salt Lake City, to assess WH – wildlife interactions. Status: Complete. This research group has published two papers demonstrating that native wildlife are negatively affected by the presence of wild horses near water sources (Hall et al. 2016, 2018).	The study is documenting wild horses competing with wildlife and livestock.
Arizona Game and Fish Department	Multi-year *(funded by AGFD)*	Goal: Assess impacts of wild burros on indicators of biodiversity. Status: Field data collection complete; analysis n progress. Field work included measurements of bird, small mammal, bat, herpetological, macroinvertebrate, and vegetation communities, as well as burro scat index counts, in areas with estimated burro density.	Wild burro impacts in Arizona have not been systematically assessed prior to this study.

Other WHB-related projects funded entirely by BLM partners or other sources			
University of Nevada, Reno	Ongoing *(not BLM-funded)*	Goal: Use vegetation sampling, Greater sage-grouse locations, and horse, wildlife and livestock fecal transects to characterize ungulate versus sage-grouse habitat use in and near the Sheldon National Wildlife Refuge. Status: Complete. Heavy grazing by wild horses or livestock reduces sage-grouse chick survival, but effects on nest survival less so (Street 2021). The project may continue with post-doctoral research.	The study confirms that wild horses impact Greater sage-grouse population growth.
University of Technology, Sydney (Australia); Effect of burro removal from California springs	2019-2023; $0 (*NPS permitted; externally funded*)	Goal: Study the ecosystem attributes (flora, fauna, physical measures) before and after burro removals from Death Valley NP and the Mojave National Preserve. Status: Ongoing. Predation on burros by cougars, and burro behavioral avoidance of water sites where cougars are found, has been documented.	The study might suggest that predation risk reduces burro use at springs, and increases riparian habitat value to other species.
University of Arizona	2015-2018 *(not BLM-funded)*	Goal: Document ecological effects of wild burros in desert riparian areas Status: Complete. Study documented that burros dig 'wells' that can allow for water access in sandy / gravelly beds of intermittent streams (Lundgren et al. 2021)	Wild burros appear to facilitate water availability and seedling germination in some environments.
University of Nevada Reno; Nevada riparian management in WHB use areas	2018-2019; $0 *(funding from USFS)*	Goal: Collate and consider existing records on riparian conditions and wild horse numbers in areas of Nevada. Status: UNR began to collect the desired records in 2020.	This study is looking for correlations between wild horse use and riparian condition.
University of Wyoming; Animal-plant interaction ecology on Wyoming rangelands	2015-2020; $0 (funding from WY DOT)	Goal: Review available literature on wild horse interactions with livestock and native ungulates. Status: Several review papers completed, addressing dietary overlap (Scasta et al. 2016), human dimensions (Scasta 2019a, Scasta et al. 2020), and a review of BLM animal welfare outcomes at gathers (Scasta 2020).	The review of capture outcomes confirms that BLM has lower mortality than most other wildlife capture operations.
Arizona State University	2014-2016; $0 *(not BLM-funded)*	Goal: Use camera traps to monitor burro behaviors near water sources. Status: The study documented burros digging out water sources in sandy washes, creating 'wells' of water that are then available for other wildlife species. (Lundgren et al. 2017).	Burros may facilitate water availability for other wildlife species in some areas.
UC Davis Emeritus researcher; Non-surgical sterilization of mares	2016-ongoing; $0 *(self-funded)*	Goal: Test the use of cyanoacrylate glue in mare oviducts, to prevent fertility. Status: Complete. The technique is exacting. A pilot study of 6 treated mares indicated success for up to 3 years or more.	This sterilization method is relatively non-invasive. It requires uncommon veterinary expertise.

Other WHB-related projects funded entirely by BLM partners or other sources			
New Mexico State University / USGS Wildlife Coop Unit; Ecology of feral burros on the National Training Center Fort Irwin, California	2015-2017; $0 (*funded by Dept. of Defense*)	Goal: Monitor the movements of radio-collared burros, the effectiveness of PZP vaccines for jennies, and of vasectomy for jacks. Status: 19 jennies were treated with PZP, including 7 that were immobilized with etorphine + xylazine. 24 jacks were vasectomized. Data collection concluded in 2017. Results are in press (Gedir et al. In press).	Wild burro jenny fertility levels can be affected by fertility control vaccine treatments.

Literature Cited

The following list is of references noted in the table above, and mainly includes work resulting from BLM funding or logistical support. Omission of any such work is not intentional. Many other WHB-related scientific publications have been published since 2005, but are not included here.

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