Stop Horsing Around:

An economic analysis of wild horse conservation programs to reduce overpopulation in Western America

by

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For Economics 482

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Year 2017 *Winner of the Douglas D. Purvis Prize in Economics*

I. Introduction

This paper identifies and critically assesses impacts from overpopulation of and conservation policy for wild horses and burros within the Western United States. The Wild Free-Roaming Horses and Burros Act of 1971 (WFRHB) requires the protection, management, and control of wild free-roaming horses[1] or mustangs on public lands, one of the most sacred and iconic species of America. Under the Act, wild horses are to be maintained in good condition, protected from abuse, slaughter, harm, and exploitation and managed to "preserve and maintain a thriving natural ecological balance and multiple-use relationship" on public land.[2] The US Department of the Interior Bureau of Land Management (BLM) is tasked with policy design, implementation and enforcement of WFRHB. Over the past four decades, several factors, including BLM ineffectual enactment of WFRHB, have contributed to an exponentially increasing mustang population, overgrazing and degradation of public rangelands, starvation, dehydration, rampant disease, overfull holding facilities, and a significant deterioration in wild horse welfare. Achievement of WFRHB competing goals in an environmentally and economically sustainable manner under current policies and practices is practically impossible.

The dynamics of wild horse populations demonstrate why current population size is a major source of policy concern. The wild horse population has more than doubled since WFRHB passed in 1971 and is projected to continue to double ever four to five years.[3] In 2016, wild herd levels exceeded 67,000 which far surpasses the Appropriate Management Level (AML)

[1] Wild horses include horses and burros unless otherwise indicated.
[2] The Wild Free-Roaming Horses and Burros Act of 1971 (Public Law 92-195).
[3] The 1971 population was estimated at 25,000. National Horse & Burro Rangeland Management Coalition. (2016)

benchmark population size of 27,000 set by the BLM;[4] the AML benchmark is set to "achieve and maintain a thriving natural ecological balance on the public lands."[5] Under current policies, BLM states that the wild horse population will soar to 145,000 by 2020. The magnitude of herd reduction required to meet the AML benchmark is staggering.

Wild horse and burro management challenges, whether economic, environmental, or welfare-related, are a long-standing part of the American natural and cultural heritage. Division and strive about how to solve the wild horse overpopulation problem exists across the U.S., particularly in the agricultural and rangeland sectors. On one side, ranchers seek reductions in wild horse populations to protect their livelihoods; overpopulation degrades the environment and depletes food and water resources to such an extent that cattle/beef profitability are adversely impacted. On the other side, animal rights and horse advocates look to protect the animals and allow the mustangs to roam free.

BLM has administrative discretion to decide how to discharge its public duties of care and population control of wild horses. The agency is taking steps and considering new options to mitigate and lessen the negative impacts of wild horses in Western United States. BLM seeks solutions wherein wild horses are protected, rangeland is preserved, the livestock industry is unharmed and budgetary constraints are met. Programs currently in use include wild horse removals, adoption, fertility control and continuing research. Although BLM program expenditures have increased more than five-fold from $15 million in 1998 to $80 million in

[4] Herd Area and Herd Management Area Statistics (2016)
[5] Ray G. Huffaker et al (1989).

2016, the wild horse overpopulation problem continues to worsen.[6]

The paper proposes an innovative policy that can mitigate the wild horse overpopulation problem by raising adoption rates and lowering BLM holding costs. Briefly, the paper develops an economic model wherein BLM chooses a proportion of horses in off-range holding to train as well as the training level in any given period. Although training is costly, trained horses command a higher market price and have a higher probability of adoption. Comparative statics are presented to demonstrate how trade-offs and the solution depends upon a set of exogenous economic and biological parameters. The model shows that the solution will increase the efficiency of the current BLM adoption program.

The paper is organized as follows. Section II gives an overview of the causes and consequences of overpopulation, as well as relevant current policy solutions. Section III introduces and solves the training choice model and demonstrates that this solution will increase the efficiency of the current BLM adoption program, reduce the overpopulation of wild horses and lower off-range holding costs. Section IV examines other controversial methods to reduce overpopulation. Section V concludes the paper with an argument for further research on and implementation of an optimal mix of discussed policies.

II. Background

Impacts

Wild horse overpopulation generates costs to society, negative environmental externalities on public lands as well as population control costs. We'll briefly identify and discuss issues

[6] Office of the Inspector General. US Department of the Interior. (2016) "The Bureau of Land Management's Wild Horse and Burro Program is not Maximizing Efficiencies or Complying with Federal Regulations."

related to negative externalities and summarize recent trends in BLM wild horse population control program costs.

At a certain point, overpopulation of a species within an ecosystem will disrupt the ecological and healthy flow of the natural cycle. Despite the existence of 31.6 million acres of public rangeland, excess numbers of wild horses cause environmental degradation. Mustangs widely roam public rangelands and, as herd sizes increase, so too does the degree of environmental damage. For example, the “trampling effect”, caused by horse feet activity across the barren lands and biotic crusts (a key composition material of grasslands), leads to irreversible damage; erosion, degraded, barren rock replaces the fertile environment resulting in desertification.

A 1971 BLM population count indicated that increases in the wild horse population had resulted in overgrazing of public rangelands. Neither public goal of an “optimal number of wild horses that results in a thriving natural ecological balance and avoids deterioration of the range” nor an appropriate management level (AML) were being met.[7] With the gap between on-range herd sizes and the AML increasing each year, the ecosystem is becoming increasingly unbalanced and unsustainable, placing both the ecosystem and the species at risk.

As the global climate changes, hotter weather and droughts will occur more often on the public rangelands reducing already scarce water and food resources. Increasingly scarce water resources will exacerbate the current stiff competition for water and will ultimately lead to increases in dehydration and death, particularly among the young, old and sick. Droughts and

[7] Animal Protection Institute of America, 109 IBLA 112, 119 (1989)

overgrazing have also caused inadequate forage quality and availability. Climate change and current management practices are projected to create further forage shortages in the future. Inadequate forage can weaken immune systems increasing the susceptibility of wild horses to disease and infection while starvation can lead to death.

Wild horses compete for food and water within herds and with other species. The Ecological Society of America stipulated that "feral horse grazing at the utilization levels…can affect the ecological function of semi-arid rangelands and may degrade the habitat value of these communities for associated wildlife."[8] In an already degraded environment, wild horse food and water demands increases survival challenges facing other species. Dominant behavior and size of mustangs along with their interaction with other wildlife may lead certain native species to avoid areas in which they originally occupied. Likewise, the grazing actions of wild horses reduce the quality and quantity of vegetation available for other wildlife to find suitable habitat among the wild horses.[9]

Overgrazing and degradation of public range lands are also caused by the agricultural and rangeland sectors of the economy. BLM has significantly restricted the distribution of (free) public range lands grazing permits for private livestock to due reduced forage rates and yield caused by overgrazing. Grazing permits allow ranchers to freely graze cattle, sheep and other livestock on public lands. BLM issued 18 million animal unit monthly's (AUMs) to American farmers and ranchers in the 1950's but currently provides only 8.6 million AUMs.[10] The

[8]Davies et al (2014)
[9] Chris T. Bastian (1999)
[10] U.S. Department of Interior, Bureau of Land Management (2016)

agriculture and rangelands sectors view AUMs or grazing permits as an inalienable property right so the encroachment of rights due to wild horse overpopulation is a particularly contentious subject in the American Midwest.

With fewer AUMs and overgrazed public lands, cattle herd size as well as care is declining, reducing cattle industry profits. Lower forage rates and lack of forage nutrients lead to lower cattle weight and thus lower market value of beef sales for ranchers. These negative impacts are a challenge, economically and politically, as a designated use of public land reserves is to stimulate the cattle industry.

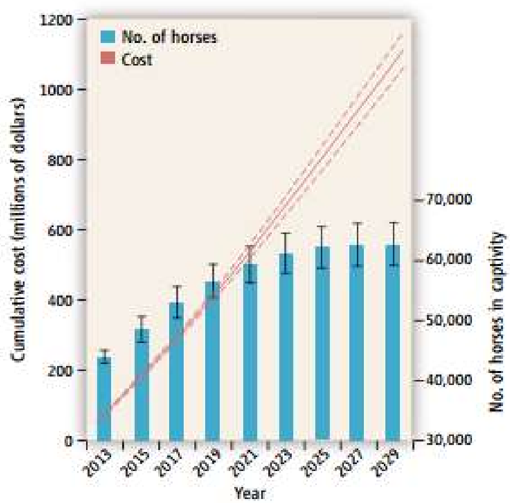
After implementation of WFRHB in 1971, wild horse numbers continued to increase and public rangelands to deteriorate to the point where cattle and other animals were dying of starvation. The American Horse Crisis stated that the land of Western United States is depleted; so much so that there is not enough food and water left to feed cattle, let alone wild horses[11].

Current Programs and Policies

BLM is taking steps to mitigate and lessen the negative impacts of wild horses in Western United States. The primary BLN program is the removal or round-up of wild horses from public rangelands to off-range sites. Wild horse removal is outsourced to private contractors. BLM inspects each round-up upon arrival and administers any required care, including vaccinations, farrier work or other treatments. From there, wild horses may be held in short-term corrals, long-term pastures, and eco-sanctuaries.[12]

[11]The American Horse Crisis - Impact (2015)
[12] General Accountability Office, (2008)

The largest BLM budget allocation is for off-range holding costs. As of March 2017, the annual cost of feeding and caring for 46,015 off-range wild horses and burros was about $50 million, averaging $1,065 per horse.[13,14] Off-range holding costs have increased at an increasing rate, rising from $7 million in 2000 to $21 million in 2007 to $50 million in 2016; .[15] During this period, the average annual percentage increases in holding costs and program budget were 36% and 24%, hence an increasing share of the program budget is being allocated to holding facilities.[16] As seen in the graph below, if off-range holding costs continue to increase at the current rate, nominal costs of the program would reach $250 million midway through 2020.**[17]**



Projections of U.S. captive wild horses and costs (with 95% confidence intervals). (see SM for more details).

In 1973, BLM implemented a nationwide auction process called the Adopt-A-Horse initiative; the program reduces off-range holdings which, in turn, keeps wild horses from slaughter and reduces misuse. Under the initiative, wild horses can be purchased for adoption

[13]US Department of the Interior Bureau of Land Management.
[14] In 2016, it cost $165 to capture a horse and $2.25/day to sustain the horses in captivity.
[15] Ibid.
[16] General Accountability Office (2008)
[17]Elizondo et al (2000)

by private owners to be cared for on private lands. BLM assesses potential adopters and considers ability to care and provide for adoptees; with BLM approval, private individuals may adopt multiple wild horses. The BLM sets a $125 fee for adoption or sale, and as of 2015, the adoption process costs $6.3 million.[18] Adopters continue to be monitored by BLM to ensure adoptees are kept from slaughter and remain in healthy environments. The adoption program also provides support to adopters to aid in the transition of wild horse from on-range to off-range lifestyles.

To date, the BLM has adopted out more than 235,000 wild horses and burros nationwide.[19] While the adoption program continues to be the most successful non-kill method for removing wild horses from public ranges, the efficacy of the program is declining as adoption rates fall. At the apex of the program, adoptions reached about 8,000 per year.[20] Since 2012, adoptions of wild horses and burros average about 2,500 a year.[21]

From 2012 to 2016, roughly sixty per cent of wild horses removed from public lands were adopted.[22] The remaining forty per cent are moved to BLM short-term or long-term holding facilities; unadoptable horses can remain in long-term holding facilities until death, often accruing high cumulative holding and medical costs. Off-range holding facilities are located through Western and mid-Western United States and include facilities on private lands: BLM can pay private contractors per-horse, per-day for unadopted wild horses to occupy private lands. BLM has the authority to remove horses from off-range holding facilities by means of

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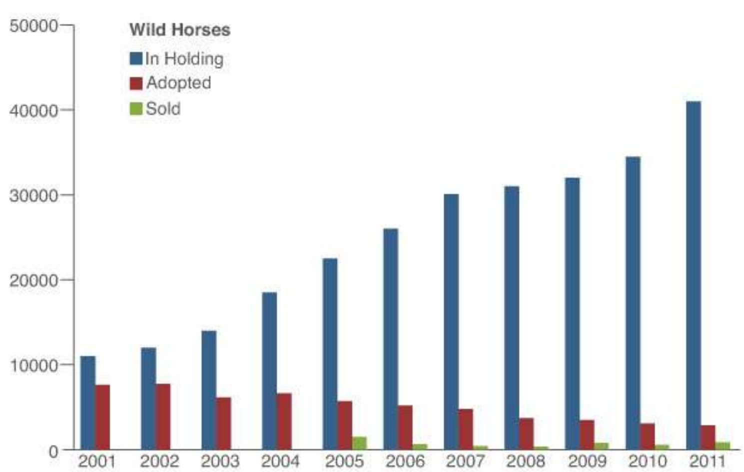
[18]Ibid.
[19]U.S. Department of Interior, Bureau of Land Management
[20] National Horse & Burro Rangeland Management Coalition. (2016).
[21]U.S. Department of Interior, Bureau of Land Management
[22]Ibid.

lowest cost (including selling them to slaughter houses), however, the exercise of such discretion is curtailed under a moratorium on use of taxpayer dollars as well as public opinion.

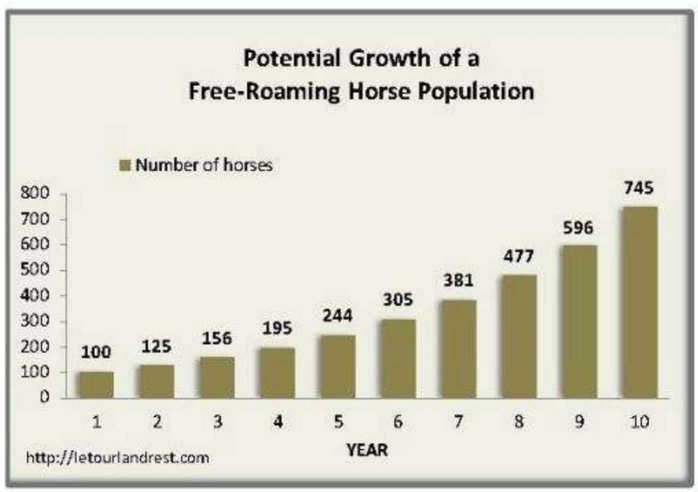
It is important to note that wild horses bear an immeasurable cost when placed in off-range holding. Wild horses, like domestic horses, are herd and prey animals with highly stable social hierarchies. Changing any horse's environment causes trauma to the horse; experts believe horses have long memory, suffer separation anxiety and depression from separation from or death of loved ones and that distress can be long-lasting.[23] Activists believe current treatment and living conditions of wild horses held in off-range holding facilities are inadequate and detrimental to the current and future welfare of these horses.

Relinquishment of adopted horses also occurs. In 2016, 101 of the 2,331 adopted wild horses were relinquished or returned to BLM. In previous years, when adoption numbers were higher, it was typical for 300 to 500 wild horses to be returned by adopters who were "in over their heads."[24] Relinquished horses are returned to off-range holding facilities.



[23] Like an elephant, a horse never forgets.
[24] Nicole Rivard (2016)

The graph above illustrates the unsustainability of current BLM programs. During the period 2001 to 2011, the number of wild horses (blue bars) in holding increased every year, sometimes at exponential rates. At the same time, wild horse adoptions (red bars) and sales (green bars) steadily declined. As a result, the gap between wild horses in holding and out-going (adoption/sales) increased dramatically during the period. This gap continues to increase. By 2017, the combination of continuing rapid wild horse population growth, escalating off-range holding costs, low and stagnant adoption rates, and relinquishments makes the adoption program, as is, an ineffectual solution on its own. For the adoption program to become sustainable, the program must find ways to increase adoptions and options to deal with the unadopted and relinquished horses to control off-range holding facilities costs.



As shown in the graph above, the population of free-roaming horses can double in size every four years and triple every six years. To control population growth rates, BLM uses fertility control to reduce the number of roaming wild horse births. Fertility control can be achieved through sterilization of individual horses or hand-administering a two-year fertility control vaccine, known as *porcine zona pellucida* (PZP), to mares. BLM claims PZP has an effectiveness of 90% for preventing pregnancies and continues to be used to reduce foaling.[25]

Use of PZP requires an initial one-time cost of approximately $300 per horse and two-year population monitoring to make sure the contraceptive is successful.[26] Bartholow (2007) estimates the cost of fertility control monitoring at approximately $7,000 per HMA per year. In addition, he finds that the two-year contraceptives could be combined with experimental three-year contraceptives and a modified herd-sex ratio to reduce the number of horses in long term holding by 17% over a 20-year period. Garrott and Oli (2013) found that if the PZP was used more widely and generously, it could help to curtail wild horse fecundity, and possibly lead to birth rates being reduced to half. Interestingly, Garrott and Oli (2013) estimate $16,110 per prevention of each additional birth could be saved regarding long-term holding. However, in a June 2013 report, the National Academy of Sciences (NAS) found that "no highly effective, easily delivered, and affordable fertility-control methods were currently available to manage wild horse population growth" and urged BLM to use better research tool.[27]

Finally, BLM has recently added a wild horse training program to its program mix to increase the attractiveness of wild horses to potential adopters. A 2016 study shows that although 18% of wild horsse would be adopted under current adoption rules without training, nearly all would attract bids of $125 with training.[28] We now turn to presenting and discussing our model in Section III which shows that gains from a training policy can be maximized by designing an efficient training program.

[25] Bartholow (2007)
[26] Ibid.
[27] U.S. Department of Interior, Bureau of Land Management.
[28] Elizondo et al. (2016)

III. Model

The model identifies and analyses BLM choices related to wild horse training. BLM may choose the number of wild horses to train as well as individual wild horse training level to maximize agency payoff. While training wild horses is costly, training yields several benefits. The primary benefit of training to BLM is the increase in wild horse adoption rates due largely to higher net benefits of private horse ownership.[29] Higher adoption rates lead, in turn, to higher BLM revenue and lower BLM holding costs. Other benefits include cost-savings realized from higher turnover rates in holding facilities; holding space is made available more quickly as the turnover rate increases, allowing BLM to fill the space with newly rounded-up wild horses. By increasing adoption rates and clearing holding areas faster, BLM can attain any wild herd stock goal more economically. Thus, higher adoption rates could ultimately reduce the stock of roaming wild horses hence other costs arising from wild herds such as environmental costs.[30]

Two simplifying assumptions are made to study the comparative effects of choosing a training program. First, we assume homogeneous horses to abstract from horse attributes that can affect BLM choices; the homogeneity assumption can be relaxed to determine how age, quality, ability and other factors impact the choices surrounding training strategy. Second, the model is static, focusing on choices in one period; the model framework can be extended to multiple periods which would also allow analysis of fertility control, another population control

[29] As a prey animal, a horse is inherently unpredictable. In general, the higher the level of training a horse receives, the more predictable and the better behaved is the horse, yielding higher net benefits of ownership.

[30] Although the model does not look at the choice of herd level *per* se, the model suggests that cost-savings attained from a cost-effective training program could be used to attain further reductions in wild horse and burro populations.

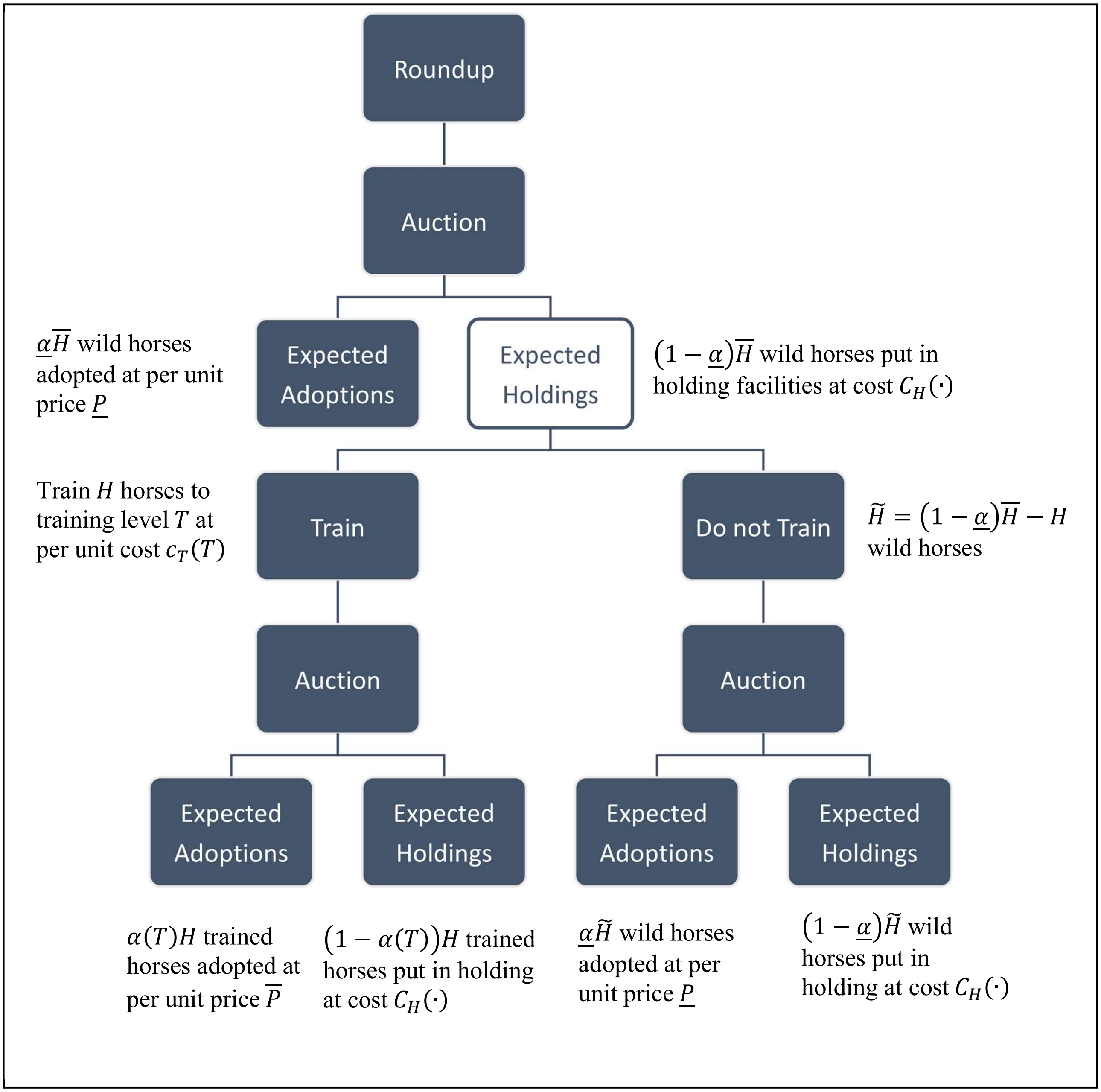
strategy used by BLM.

We assume BLM initially rounds up $\overline{H}$ healthy wild horses from public range lands; the choice of $\overline{H}$ is exogenously determined and may or may not lead to the attainment of the ALM.[31] Immediately after the initial roundup, BLM holds an auction for the adoption of $\overline{H}$ wild horses. Let $\underline{P}$ be the adoption price of a wild horse and $\underline{\alpha}$ be the probability that a wild horse is adopted. For simplicity, assume that, in any auction, some wild horses will be adopted, $\underline{\alpha} > 0$, and that transactions costs are zero for buyers and seller. The expected number of adoptions in the initial auction is thus $\underline{\alpha}\overline{H}$. BLM will transfer the unadopted $(1-\underline{\alpha})\overline{H}$ wild horses to holding facilities. The cost of holding horses $C_H(\cdot)$ is population dependent and is assumed to be weakly convex with $C_H' > 0$ and $C_H'' > 0$. Note that although the holding cost function may shift due to the standard of horse care provided, BLM cannot choose a level of horse "care" per se in the model.

Post-auction, we model BLM as a single decision maker with two choice variables, the number of horses to train, H, and the (constant) training level per horse, T. Training increases the value and desirability of wild horses to potential horse buyers.[32] Buyers are willing to pay a higher adoption price $\overline{P}$ for trained horses where $\overline{P} > \underline{P}$, that is, the adoption price of a trained horse strictly exceeds the adoption price of a wild horse. While training increases the adoption probability, $\alpha(T)$, there are diminishing returns to training hence $\alpha' > 0$ and $\alpha'' < 0$.[33] We

[31] We assume $\overline{H}$ wild horses are sufficiently healthy to be sold to private individuals; wild horses are checked by veterinarians prior to auction and only horses that are believed to be healthy are auctioned.
[32] Indeed, the price of horses is strictly increasing in training level in horse markets generally.
[33] Training also increases the probability that an adopted wild horse will be kept by the owner. The high return rate of adopted wild horses is an increasing problem for BLM.

assume that $0 < \underline{\alpha} < \alpha(T) < 1$ where $\underline{\alpha} = \alpha(0)$ is the adoption rate with no training and $\alpha(T) < 1$ means that there is no feasible training level that ensures certain adoption. Finally, the per unit cost of training a horse, $c_T(T)$, is weakly convex in T so that $c_T' > 0$ and $c_T'' \geq 0$; aggregate training costs are $c_T(T)H$.



BLM training decisions begin at the first (unfilled) Expected Holdings node. If BLM chooses to implement a training program, then it may choose to train H horses to training level T at a training cost per horse of $c_T(T)$. Of the trained horses, BLM expects that $\alpha(T)H$ will be adopted at a per unit price $\overline{P}$. Unadopted trained horses are placed in holding facilities at an expected total cost of $\big(1-\alpha(T)\big)C_H(H)$.[34]

BLM expected payoff from implementing a training program prior to the second auction is:

$$E[\pi_{train}(H,T)] = \alpha(T)\overline{P}H - c_T(T)H - C_H\left(\big(1-\alpha(T)\big)H\right)$$

The expected payoff from training starting with the first term is expected adoption revenue less (certain) aggregate training costs less aggregate holding costs of trained horses not expected to be adopted.

BLM expected payoff from auctioning the $\widetilde{H} = (1-\underline{\alpha})\overline{H} - H$ wild horses in off-range holding facilities after the first auction is[35]:

$$E[\pi_{wild}] = \underline{\alpha}\,\underline{P}\widetilde{H} - C_H\left((1-\underline{\alpha})\widetilde{H}\right)$$

The expected payoff is the difference between expected revenue from adopting the remaining wild horses less the expected cost of holding the wild horses not adopted.

BLM will choose $\{H,T\}$ to maximize expected payoffs $E[\pi] = E[\pi_{train}] + E[\pi_{wild}]$.

$$\max_{\{H,T\}} E[\pi] = \left[\left(\alpha(T)\overline{P} - c_T(T)\right)H - C_H\left(\big(1-\alpha(T)\big)H\right)\right] + \left[\underline{\alpha}\,\underline{P}\widetilde{H} - C_H\left((1-\underline{\alpha})\widetilde{H}\right)\right]$$

[34] For simplicity, we assume that wild horses and trained horses are held in separate holding facilities hence holding costs are separable, $C_H\left((1-\underline{\alpha})\overline{H}\right) = C_H(H) + C_H(\widetilde{H})$.

[35] Note that fixing the round-up stock of wild horses at $\overline{H}$ ignores potential relinquishment of wild horses adopted in the first auction. Any relinquishments will increase in the number of unadopted horses in holding facilities.

The first-order condition for optimal choice of number of horses to train is[36]:

$$\frac{\partial E[\pi]}{\partial H} = \left[\alpha(T)\overline{P} - c_T(T) - (1-\alpha(T))C'_H\left((1-\alpha(T))H\right)\right]$$
$$+\left[-\underline{\alpha}\,\underline{P} + (1-\underline{\alpha})C'_H\left((1-\underline{\alpha})\widetilde{H}\right)\right] = 0$$

Simplifying and rearranging yields

$$H^{*}\colon\ \alpha(T)\overline{P} - \underline{\alpha}\,\underline{P} = c_T(T) - \left[(1-\underline{\alpha})C'_H\left((1-\underline{\alpha})\widetilde{H}\right) - (1-\alpha(T))C'_H\left((1-\alpha(T))H\right)\right] \quad (1)$$

The left-hand side of equation (1) is the (constant) expected benefit of training an additional wild horse, $E[MB]$. $E[MB]$ is the expected adoption price differential between a trained horse and a wild horse, or alternatively, the expected gain in adoption revenue. The right-hand side of (1) is the expected marginal cost, $E[MC]$, of placing a horse in training: the cost of training one horse $c_T(T)$ less the expected incremental holding cost-savings in the square bracket. Higher adoption rates for trained horses and holding cost separability ensures that expected marginal holding costs will be lower for trained horses thus the term in square brackets, call it $\Delta E[C'_H]$, is positive. Expected marginal costs are increasing in H because $\Delta E[C'_H]$ is decreasing in H. For a given training level T, the optimal number of horses to train is depicted in Figure 1 as the intersection point between the expected marginal benefit and expected marginal cost curves.

The first-order condition for optimal choice of training level per horse is:

$$\frac{\partial E[\pi]}{\partial T} = \left[\alpha'(T)\overline{P} - c'_T\right]H - C'_H\left((1-\alpha(T))H\right)(-\alpha'(T)H) = 0$$

[36] Note that $\frac{\partial \widetilde{H}}{\partial H} = -1$.

$$T^*:\ \alpha'(T)\overline{P} = c_T' - \alpha'(T)C_H'\left(\left(1-\alpha(T)\right)H\right) \quad (2)$$

The left-hand side of equation (2) is the expected benefit of an incremental unit of training, $E[MB]$. The expected gain in marginal adoption revenue is due to two factors: additional training increases the marginal probability of adoption, $\alpha' > 0$, and results in a higher adoption price, $\overline{P}$. $E[MB]$ is downward-sloping because the marginal probability of adoption is decreasing in T. The right-hand side of (2) is the expected marginal cost incurred from additional training, $E[MC]$. $E[MC]$ is the difference between the certain marginal training cost, c_T', less the expected marginal holding cost-savings; since training increases adoption rates, trained horses in holding hence holding costs of trained horses are strictly decreasing in T.

Optimal strategies (H^*, T^*) can be found by simultaneously solving equations (1) and (2). Given the other strategy is chosen optimally, the optimal number of horses to train, H, and optimal training level per horse, T, are the intersection points of the expected marginal benefit and expected marginal cost curves depicted in Figures 1 and 2 below.

Figure 1. How many wild horses H to train?

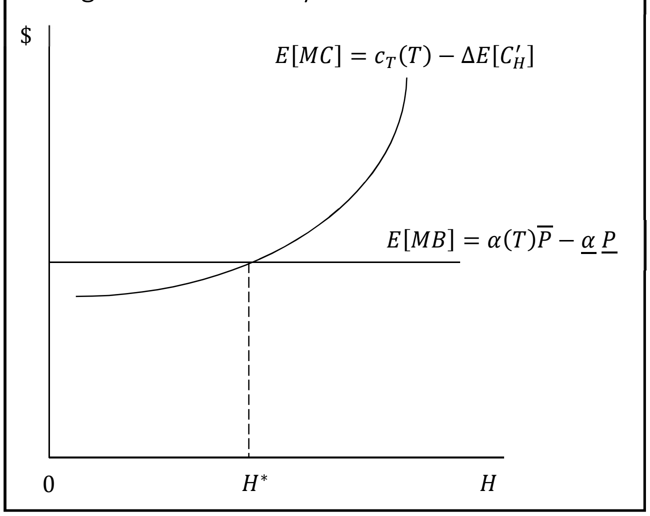
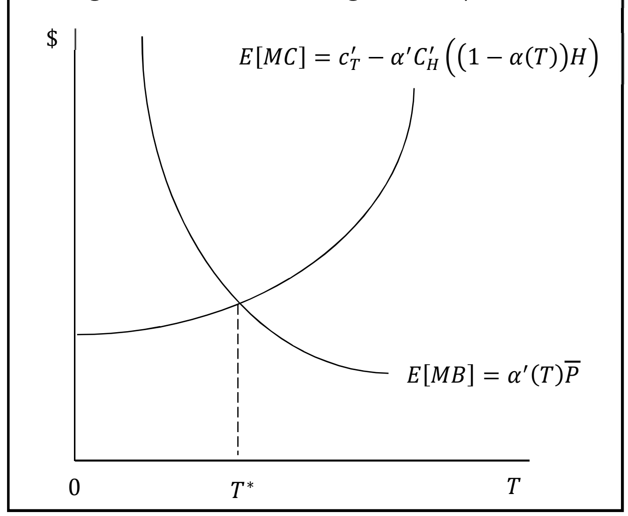


Figure 2. What training level T per horse?



The model has four exogenous variables, $\{\overline{H}, \underline{P}, \overline{P}, \underline{\alpha}\}$, the number of wild horses rounded up, the adoption prices of wild and trained horses, respectively, and the adoption rate for wild horses. To understand how the optimal training program (H^*, T^*) depends upon exogenous variables, totally differentiate equations (1) and (2) and apply Cramer's rule to find the comparative statics of interest.[37] We'll briefly discuss the impact on the optimal training program of increases in each exogenous variable in turn.

The number of horses trained and the training level should increase as the roundup $\overline{H}$ increases, that is, $\frac{dH}{d\overline{H}} > 0$ and $\frac{dT}{d\overline{H}} > 0$. Training a higher proportion of the wild herd to a higher training level leads to a higher likelihood of more horses being adopted at the higher price and fewer horses in holding facilities post-auction. Increasing both components of the training program is a win-win for BLM as adoption revenue increases and holding costs decrease post-auction. An increase in $\overline{H}$ leads to a rightward shift in $E[MC]$ in Figures 1 and 2, resulting in higher levels of H and T; a higher level of T, in turn, raises the $E[MB]$ and $E[MC]$ of H which could result in a lower increase in H. The expected gain in the adoption price differential is due to the increase in the probability of adoption of trained horses while the expected increase in marginal costs is due to the reduction in the expected holding cost-savings.

It's easy to see that an increase in either the probability of wild horse adoption, $\underline{\alpha}$, or the adoption price for wild horses, $\underline{P}$, will reduce BLM incentives to pursue a training program. An increase in either variable leads to a reduction in the number of horses trained as well as the training level because of the lower expected price differential paid for a trained horse. The downward shift in the $E[MB]$ of H in turn shifts $E[MC]$ of H and T upwards due to higher

[37] Derivation of comparative statics results are available upon request.

expected marginal holding costs.

Finally, an increase in the adoption price of trained horses, $\bar{P}$, increases the incentive of BLM to train more horses to a higher training level, that is, $\frac{dH}{d\bar{P}} > 0$ and $\frac{dT}{d\bar{P}} > 0$. A higher $\bar{P}$ shifts $E[MB]$ of H and T upwards in Figures 1 and 2. Secondary effects on H of increasing T are an additional upward shift in $E[MB]$ and an upward shift in $E[MC]$, leading to a possible dampening or amplification in the increase in H. A secondary effect on T of increasing H is a downward shift in $E[MC]$.

IV. Other policy options

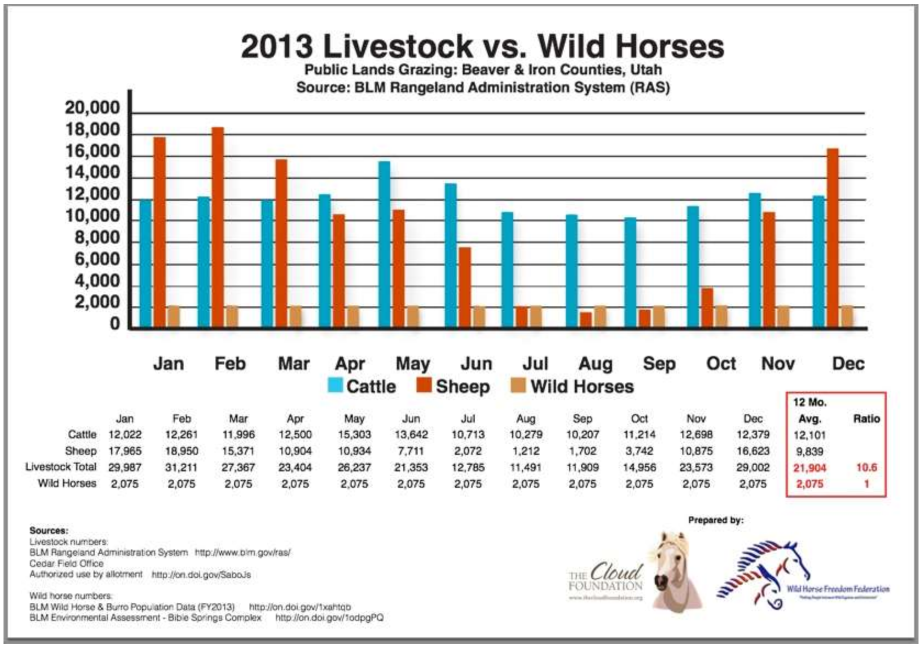
This section addresses other, more radical policy options to reduce wild horse overpopulation not currently in use. Inclusion and optimal combination of all feasible methods of controlling wild horse populations will always maximize social welfare and result in the most cost-effective control strategy. Whether either of these strategies can improve social welfare is an empirical question.

Firstly, the decline of natural predators is a main driving force in exponential wild horse population growth. When roaming wild horses graze on rangeland without a significant threat of predators, natural causes of death are limited to disease, dehydration, age, and starvation. One policy option is thus to (re)introduce a natural predator species to the public range land. The process of introducing a native predator to horses is an indirect way of tackling overpopulation as the native species may take to “lesser” animals in the range instead of the larger wild horses. Thus, prior to any predator population increase, BLM should be required to demonstrate that the predator can reduce wild horse populations without significant population effects on other species.

The most obvious natural horse predator to reintroduce is the gray wolf. The gray wolf population on public lands significantly declined over the past two hundred years. Wolves were culled by ranchers and hunters during the late 1800's and early 1900's to curtail livestock deaths as well as by government-sponsored predator control programs. By 1973, gray wolves were near extinction in the lower 48 States and were listed as an endangered species under the US Endangered Species Act. Successful US Fish and Wildlife Service (FWS) recovery programs have resulted in sufficiently high wolf populations to de-list the species in several states between 2007-2008. Wolf population targets are not currently set taking into account external benefits of reducing wild horse populations hence are likely too low.

The efficacy of increasing a natural predator like the gray wolf largely depends upon wolf population management. Like wild horses, the optimal level of wolves must be controlled and monitored by FWS to avoid overpopulation. Wolf population can be controlled using hunting permits or fertility control; to avoid past disasters, hunting restrictions must be monitored and enforced by FWS.

A second policy option entails further restricting access of privately owned livestock to public lands. Presently, public ranges are common property. Overgrazing of livestock such as cattle and sheep is a major contributor to the environmental degradation of public lands. The graph below dramatically illustrates the relatively small contribution of wild horses to public lands grazing in Utah. Thus, solving the problem of public land degradation entails controlling public lands grazing by livestock herds as well as wild horse populations.



Currently, cattle grazing numbers are restricted to the allotted Homogeneous Response Units (HMUs) and grazing permits are freely distributed to ranchers. Failure to internalize the negative externality of cattle grazing on public lands results in excessive HMUs hence too many permits. Using livestock grazing receipts, BLM estimated that cattle outnumbered wild horses and burros on public lands by 37:1 in 2015.[38]

BLM could implement a tradable grazing permit system for livestock and wild horses. Once a public lands use grazing level is determined, BLM could issue the corresponding number of grazing permits.[39] A grazing permit market will emerge in which BLM, horse activists, ranchers, and other interested parties could buy and sell permits. Depending upon the marginal value of grazing to market participants, outcomes could include horse activists buying permits from ranchers to donate to BLM to raise the maximum allowable wild horse herd size.

[38] U.S. Department of Interior, Bureau of Land Management.

[39] BLM can distribute grazing permits in any way desired, including an auction, as the initial distribution of tradable permits does not have efficiency consequences.

Under a tradable permit system, a positive market price for cattle grazing permits would reduce cattle overgrazing on public lands, allowing for lower wild horse removal rates. If the optimal number of permits are issued, the market-clearing permit price will fully internalize the marginal external costs of grazing and permits will be allocated cost-effectively across users. Charging for the use of public lands will likely reduce ranchers' demand for permits leading to less overgrazing caused by cattle.

Trading systems are used effectively world-wide to allocate various resources in a cost-effective manner, including clean air, clean water, fish, and forests. However, implementing a tradable grazing permit system for managing public lands will involve fundamental changes in the structure and provisions of federal grazing leases and would require the resolution of myriad complex issues. Such a solution may not be feasible until some point in the future given the current distribution of wealth, power and entitlements among stakeholders.

V. Conclusion

Without the implementation of low-cost and effective ways to remove, adopt/sell and hold wild horses, the ecological and economic sustainability of wild horses, other species and public lands will be compromised. This paper offers a rigorous solution to the overpopulation problem by presenting and solving a model that delineates the costs and benefits associated with training and allows BLM to choose the optimal training program. The efficient training program optimizes wild horse adoption rates hence reduce the number of wild horses and burros in short and long-term holding facilities. The model predicts that BLM should increase the number of horses to train as well as the training level as more wild horses are removed from public lands and as the adoption price of trained horses increases. In contrast, in high adoption periods or when adoption prices for wild horses are high, BLM should reduce the training program and invest resources in other programs.

Training is a relatively cheap short-term option available to BLM to significantly lower off-range holding costs. However, a single policy can only partially address the many exiting problems related to wild horses. For instance, training programs cannot be relied upon to adequately reduce the on-range wild horse population; to do so, the holding turnover rate of the training program must exceed the wild birth rate.

Solving the wild horse overpopulation problem ultimately requires the implementation of an optimal mix of strategies. Combining adoption and training programs with enhanced fertility control programs, pricing public land use for livestock grazing and natural predator introduction will increase human and animal welfare by inducing lower on-range wild populations and improving the quality of public rangelands. From an economics perspective, we would like to see such a mix chosen optimally to ensure BLM goals are attained at least-cost. Analysis of so many policy options would require a computable bio-economic general equilibrium model. Yet the insights into the interactions and trade-offs between and across strategies provided by large-scale simulations could potentially generate valuable policy insight.

The ability to successfully implement a mix of low-cost solutions is costly so will require adequate funding and resources, consistent monitoring, and steady efforts on all fronts from that of farmers, advocates, legislators and BLM. While research, development, implementation and enforcement of wild horse policies is costly, substantial positive economic, health, and environmental benefits will accrue from the reducing wild horse overpopulation.

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