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Opportunity costs related to feral horses: A Wyoming case study

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Abstract

Concern over the humane treatment and diminishing numbers of feral horses (*Equus caballus*) led to their protection under the Wild Free-Roaming Horse and Burro Act of 1971. The potential for rapid population growth coupled with management constraints of the 1971 Act have increased the likelihood of excessive feral horse densities in important public rangeland habitats. Excessive densities can lead to deterioration of the range resource, smaller populations of wildlife and reduced stocking rates for domestic livestock. Consequently, the potential for conflicts between wild horse and burro advocates, wildlife agencies, recreationists and livestock producers is increased.

Research concerning wild horses has largely focused on biological and behavioral aspects such as habitat and dietary requirements. Limited economic research concerning wild horses is available to aid public agencies in allocating federal lands in a multiple use context. A case study was used in this analysis to estimate opportunity costs associated with foregone wildlife and domestic livestock due to wild horses on an existing allotment in Wyoming. Results indicate the marginal opportunity costs associated with horse numbers beyond the median target level specified in the allotment management plan are greater than $1,900 per horse. Forage consumption estimates indicate the range resource could face deterioration at higher wild horse population levels. These results suggest the objectives of multiple use, sustained yield and maintaining viable wild horse populations may be met if government agencies are able to remove wild horses in a timely fashion. It is not possible to say, however, that lower wild horse levels represent a more economically efficient allocation of the range resources without estimating the total economic benefits associated with wild horses.

Key Words: economic efficiency, resource allocation, wildlife, biological and economic tradeoffs

Resumen

La preocupacion del trato humano y la disminución del número de caballos salvajes condujeron a su protección bajo el acta de 1971 de Caballos y Burros salvajes. El potencial para el rápido crecimiento de la población de caballos junto con las restricciones de manejo del Acta de 1971 ha incrementado la posibilidad de tener densidades excesivas de caballos en importantes hábitats de pastizales públicos. Densidades excesivas pueden conducir al del recurso pastizal, reducir las poblaciones de fauna silvestre y reducir la carga animal de ganado doméstico. Consecuentemente, la posibilidad de tener conflictos entre los defensores de los caballos y burros, las agencias de fauna silvestre y los productores de ganado ha aumentado. La investigación acerca de caballos silvestres se ha enfocado principalmente a aspectos biológicos y de comportamiento talesœ como los requerimientos de hábitat y su diet. La disponibilidad de investigación económica acerca de los caballos silvestre que ayude a las agencia públicas a asignarlas tierras federales en un contexto de uso múltiple es limitada. Un estudio de caso de Wyoming fue usado en este análisis para estimar los costos de oportunidad asociados con la reducción de ganado y fauna silvestre debida oœa los caballos salvajes. Los resultados indican que los costos marginales de oportunidad asociados con el número de caballos silvestres mas alla del nivel medio especificado en el plan de manejo de asignación son superiores a los $1900 dolares por caballo. Las estimaciones de consumo de forraje indican que con poblaciones altas de caballos el pastizal podrí deteriorarse. Estos resultados suguieren que los objetivos de uso múltiple, rendimiento sostenido y mantene poblaciones viables de caballos úsalvajes pueden ser logrados si las agencias de gobierno son capaces de remover los caballos de manera oportuna. Sin embargo, sin estimar los beneficios económicos totales ascociados con los caballos salvajes, no es posible decir que poblaciones bajas de caballos representan una asignación mas econ micamente eficiente de los recursos del pastizal.

Concern over the humane treatment and diminishing numbers of wild or feral horses (*Equus caballus*) led to the Wild Free-Roaming Horse and Burro Act of 1971 (Hyde 1978). The original act authorizes the Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) to remove feral horses in excess of the ecological balance from public rangelands in 11 western states (Fisher 1983).

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Public land managers have faced 2 constraints when removing horses. First, roundups have been impeded by judicial actions brought about by animal rights activists (Huffaker et al. 1990). Second, the BLM has not found a cost effective way to dispose of unclaimed captured horses that meets public approval. Roundups consequently have been somewhat infrequent. Horses in federal holding pens cost taxpayers about $165 to capture and $2.25/day to sustain in captivity (Huffaker et al. 1990). According to Godfrey and Lawson (1986), BLM expenditures per adopted animal were between $600 and $1,800 from 1976 through 1985. Nack (1988) found the roundup program coupled with unclaimed horses cost the public $92 million between 1980 and 1988.

Rapid population growth coupled with horse removal constraints have resulted in high feral horse densities in important habitats on many public rangelands (Krysl et al. 1984, Eberhardt et al. 1982, Cook 1975). High densities have led to deterioration of the range resource, smaller populations of wildlife and reduced stocking rates for domestic livestock (Cook 1975, Fisher 1983).

Since the passage of the Public Range Improvement Act in 1978, research has largely focused on the biological and behavioral aspects of wild horses. Most research indicates similarities in habitat selection and diet composition between feral horses, big game species, and domestic livestock (McInnis and Vavra 1987, Krysl et al. 1984, Miller 1983, Denniston et al. 1982, Rittenhouse et al. 1982, Smith et al. 1982, Salter and Hudson 1980, Olsen and Hansen 1977). Applied economic research concerning wild horses and the allocation of pubic range in a multiple use context has been sparse.

Godfrey (1979) and Godfrey and Lawson (1986) concluded that the wild horse program has been relatively expensive. Godfrey and Lawson (1986) found wild horse adopters often incurred relatively large expenses for undesirable horses. They suggested that a greater understanding concerning the demand for wild horses could point to cost reduction strategies for the adoption program.

According to the interpretation of federal courts[1], the Federal Land Policy and Management Act cannot meet multiple-use and sustained-yield principles dictated in the act and give an exalted status to either livestock or wild horses. Huffaker et al. (1990) examined this issue using a bioeconomic livestock/wild horse trade-off mechanism. Their methodology was designed to allow the BLM to manipulate livestock densities (via the grazing fee) and wild horse densities (via wild horse removal rate) on an allotment that induced a sustained vegetation density satisfying multiple use, while holding the permittee's public grazing at some predetermined level. The analysis included an ecological interaction model, a wild horse population dynamics model and a model that selected the sustained livestock stocking rate to maximize present value of net benefits to the livestock producer given a competing forager. A locus of grazing fee and wild horse removal rate combinations that held present value constant was derived. Results provided theoretical implications, pointed to the need for better data and provided a framework for considering stocking rates as a function of both ecological and economic parameters. Huffaker et al. (1990) concluded that inconsistent results between their mechanism and models designed to maximize social welfare must be viewed as reasons why the objectives in federal grazing statutes may be economically inefficient.

Hyde (1978) has suggested that the wild horse issue be expressed in an economic framework that compares wild horse management costs with wild horse benefits. Qualitatively, wild horse benefits would include (1) value of recreational viewing, (2) non-consumptive values, and (3) their value to foster homes. Conversely, wild horse costs would include (1) the opportunity value for domestic livestock and wildlife foregone, (2) separable management costs, (3) cost of public scrutiny of foster homes, and (4) cost of negative externalities. An example of a negative externality created by horses would be unwanted wild horse grazing on private land. Hyde (1978) concluded that estimates must be made before allocative inferences can be drawn and that even incomplete estimates are preferable to ignorance.

The focus of this study addresses the issue of opportunity costs associated with foregone wildlife and domestic livestock due to wild horses as proposed by Hyde (1978). This focus does not allow conclusions to be drawn regarding an economically efficient allocation of the public rangeland resource. The economic analysis uses a case study approach and is based on a BLM allotment complex in Wyoming. This analysis uses the goals of the allotment management plan to illustrate the opportunity costs of wild horses.

Materials and Methods

Study Area

The case study area was based on the Whiskey Peak allotment complex (36,479 ha) administered by the BLM. Elevations on the complex range from 1,976 m to 2,812 m with annual precipitation, coming largely from snowfall, averaging 25.4 cm from 1951 to 1980. Annual high and low temperatures have averaged 13.4 and 0.33°C, with frost free days ranging from 114 at lower elevations to less than 60 at the highest reaches (Martner 1986, BLM 1990). The majority (80%) of the Whiskey Peak Allotment Complex contains sagebrush-mixed grass vegetation type (BLM 1990). The remaining vegetative types include riparian zones, aspen woodland, conifer woodland and mountain shrubland. A detailed description of the plant species by habitat class, topographic features and soils can be found in Crane et al. (1997).

Allotment Management Plan

Goals developed in the Whiskey Peak Complex Allotment Management Plan (AMP) concerning wild horse management were used to depict

[1]Cf. American Horse Protection Association, Inc. v. Frizzell, 403 F. supp. 1206 (D. Nev. 1975).

potential tradeoffs at various horse population levels (BLM 1990). The Whiskey Peak Allotment lays within the Green Mountain Wild Horse Herd Area and supports approximately 75% of the horses in this herd area. Using this 75% population adjustment, AMP target levels for the Whiskey Peak Allotment were a minimum of 128, a median of 184 and a maximum of 225. In 1992, over 500 horses occupied the Green Mountain Wild Horse Herd Management Area. That same year the BLM conducted a round-up to remove horses in excess of the specified management levels (Crane et al. 1997). Viewing the 1992 population of 500 horses as a recent historical maximum for the Green Mountain Herd Management Area, a maximum population of 375 horses was inferred for the Whiskey Peak Allotment. Population levels of 128, 184, 225, and 375 thus were used in this analysis to analyze tradeoffs and forage consumption.

The primary recreational activity on the allotment is hunting. The Green Mountain/Whiskey Peak area provides some of the best elk (*Cervus elaphus* nelsoni Bailey), mule deer (*Odocoileus hemionus hemionus* Rafinesque) and antelope (*Antilocarpa americana americana* Ord) hunting in central Wyoming (BLM 1990). Between 700 and 900 head of antelope from 2 different herd units use the Whiskey Peak complex. The target antelope objective for the complex is to provide 9,415 antelope months (i.e., provide forage for an average of 784 antelope annually). The number of mule deer using the complex ranges between 300 and 830 on a seasonal use basis, with the target objective for the complex being 7,331 deer months of forage. The population objective for the Green Mountain elk herd has been established at 500. Given this elk population objective, the Whiskey Peak Complex should provide forage for about 300 elk during the winter and somewhat fewer numbers during the other seasons. The target objective for the complex is to provide 3,544 elk months of forage. Given the objectives in the AMP, a minimum of 700 and a maximum of 900 antelope, a minimum of 300 and a maximum of 830 mule deer and a minimum of 300 elk were assumed for this analysis.

The AMP livestock grazing goals included provisions for a deferred-rotation grazing system that meets ecological objectives by allowing for forage rest periods during the growing season. The target AMP objective was to provide 8,427 Animal Unit Months (AUMs) of cattle grazing on the allotment. Given the target of 8,427 AUMS and a historical low of 4,000 AUMs reported in the AMP, maximum and minimum AUMs for cattle were specified at 8,427 and 4,000, respectively.

Another AMP goal used in this study was the specified objective of maintaining utilization of key species at 50% or less. This forage goal of take half-leave half, coupled with the above mentioned minimums and maximums for wildlife and cattle, provided constraints that were used to estimate tradeoffs between wild horses, elk, deer, antelope, and cattle.

Economic Analysis

A linear programming (LP) model was used to estimate wildlife and cattle production levels for 5 population scenarios of wild horses, including a scenario of no horses. These scenarios were developed from the AMP goals that guided management decisions on the allotment.[2] Diet composition data were used to develop grazing activity constraints in the model. Right hand side constraints were based on the 50% forage utilization assumption and the minimum and maximum target levels of wildlife previously described. The model was solved using an objective function that maximized the number of animals subject to a specified level of wild horses. This approach was consistent with management goals in the AMP, but it deviated from the traditional economic objective of maximizing social welfare. Goals established in the AMP were based on desired herd numbers and forage utilization, not on the objective of maximizing social welfare. The study objectives were to examine the opportunity cost of various wild horse populations on the allotment given the AMP population goals, not to determine if the AMP maximized social welfare.

[2]This population guideline approach is consistent with Huffaker et al.'s (1990) assumption that multiple use and sustained yield principles dictated by FLPMA do now allow a trade-off that gives one species exalted status over another, i.e., economic efficiency might dictate 1 species by given preference over another, but management agencies cannot use this as a guiding criteria under current policy.

The number of head for each wildlife species and the number of cattle in the optimal solution for each of the 5 scenarios provided the basis for estimating opportunity costs. Economic values for the different wildlife species and cattle were used to calculate the opportunity cost of foregone wildlife and cattle production at different levels of wild horses as compared to estimated production with no wild horses, consistent with procedures used by Bastian et al. (1991).

The general LP model used to estimate animal numbers was:

$$\text{Max } Z = \sum_{j=1}^{n} C_j X_j \quad \textbf{(1)}$$

subject to:

$$\sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij} X_{ij} \leq, =\geq b_i, \text{ given } X_j \geq 0 \quad \textbf{(2)}$$

where:

- Z = the number of animals
- C_j = the change in Z for a unit change in Xj, in this case Cj = 1
- X_j = the unknown number of animal j to be estimated (wild horses, cattle, elk, mule deer and antelope)
- b_i = the amount of the ith resource available (the right hand limits for animals e.g. 300 elk and forage class by season, e.g., spring grass)
- a_{ij} = the amount of resource i required per unit of activity X_j (i.e., amount of forage by class and season for each species).

The objective function maximizes the number of cattle, elk, deer, and antelope for each specified level of wild horses examined given the forage constraints and diet assumptions used. Each animal thus has an equal weight (i.e., C_j=1) in the objective function. This format was chosen to be consistent with the AMP objectives and the concept of multiple-use under FLPMA as interpreted by the courts (Huffaker et al. 1990).

Table 1. Percent composition of diet by forage class and season for each species.

Forage Category	Wild Horses[a]	Cattle[b]	Elk[a]	Mule Deer[a]	Antelope[c]
	--------	--------	% Diet	--------	--------
Spring grass/forbs	99	98	24	30	7
Spring shrubs	1	2	76	70	93
Summer grass/forbs	98	98	28	12	6
Summer shrubs	2	2	72	88	94
Fall grass/forbs	87	84	22	11	16
Fall shrubs	13	16	78	89	84
Winter grass/forbs	76	86	15	10	14
Winter shrubs	24	14	85	90	86

[a]Based on Crane et al. (1997).
[b]Based on percentages used and reported in Bastian et al. (1991).
[c]Based on Medcraft and Clark (1986).

Production of forage was based on the productivity and target requirements outlined in the AMP (take half-leave half), on standing crop estimates from Crane et al. (1997) and on the Natural Resources Conservation Service Technical Guides (USDA/NRCS 1990) for range sites in the area. Table 1 specifies percent composition of diet for each animal species by season. Grasses and forbs were combined in terms of intake and right-hand- side constraints (bi). This is consistent with recommendations by Sundstrom et al. (1973)[3] that forbs may substitute for grasses and also is consistent with procedures in Bastian et al. (1991). Percentages of each forage class by season were multiplied by the intake requirements for each animal to estimate coefficients for each grazing activity.

Diets of animals were assumed to remain constant under the 50% forage utilization assumption used in this analysis. As animal numbers increase and pressure on habitat types intensify, the diet composition will likely change in terms of individual plants and plant classes, i.e., the composition of forage input bundles consumed by animals may change as the number of animals change (Godfrey 1983). Using the constant diet assumption may therefore bias the trade-offs or marginal rates of substitution. Because little information concerning the marginal rates of substitution exist (Clary 1983), dynamic utilization considerations as animal populations vary cannot be included in this study.

Dry matter intake for wild horses, elk, mule deer, and antelope were based on estimates in Holecheck (1988).[4] Dry matter intake was multiplied by the percentages in Table 1 to estimate grazing requirements for each forage class and season. Cattle grazing activities for the analysis were based on stocker steers. Steers were assumed to graze 3 months in the summer and 1 month in the fall at an average daily gain of 0.68 kg, with beginning and ending weights of 270 kg and 352 kg. Forage consumption was calculated by multiplying percent of diet by each plant class and by kg of dry matter required by the steers each month during the appropriate season as outlined in Ensminger and Olentine (1978).

The next step was to estimate the opportunity costs of foregone wildlife and cattle production at increased wild horse levels. Opportunity costs for this analysis were defined as the foregone net benefits to society associated with reduced wildlife or cattle numbers as wild horse numbers increased. These opportunity costs were based on changes in producer and consumer surplus associated with grazing and hunting.

Net benefits to livestock producers were defined as the value of livestock weight gain on the allotment minus the costs of grazing. Perfect competition in the beef cattle market was assumed in this analysis, i.e., producers face a horizontal demand curve and the increase in supply of beef associated with grazing on the allotment does not affect the market price for cattle. Loomis (1993) stated that given this assumption, price can be used as a measure of gross willingness to pay for 1 more unit of commodity output. Loomis (1993) also defined producer surplus under these assumptions as the net benefits or change in net income from producing a commodity on public land. Since prices of beef to consumers were assumed to be unaffected by production from the allotment, consumer surplus was assumed to be unaffected.

Benefits from cattle grazing were based on the average value of weight gain per head minus average costs of gain per head for the 4 month grazing period. The average value of gain was equal to the ending weight (352 kg) multiplied by the 1985–1994 average market price for that weight class during October (Kearl 1990, Bastian 1995) minus beginning weight (270 kg) multiplied by average market price during June. Total costs of grazing were equal to the average costs of production associated with federal grazing in Wyoming plus an opportunity cost associated with the investment in cattle. The opportunity cost was estimated to be $8.83 per head using an average value approach over the grazing period (average weight over the grazing period of 311 kg multiplied by the 1985–1994 average price for that weight class over the months grazed) multiplied by a 6% yearly real interest rate for the 4 month grazing period.[5] Costs of federal grazing as reported by Torell et al. (1995) for Wyoming BLM permittees in 1992 were $13.76/AUM. Production costs used for this analysis were equal to $28.98 per steer ($13.76/AUM * 0.75 AUM coefficient * 4 months). All prices were deflated to 1982 dollars using the GNP Implicit Price Deflator. Given these estimates for the average value of gain and associated opportunity costs, the average net income or producer surplus of grazing per steer was estimated to be $12.75 per head.

[3]The study by Sundstrom et al. (1973) dealt with pronghorn diets.

[4]This assumes a static population and does not take into account a dynamic population in which new animals are born and dietary requirements change with age and weight proportions within the herd population for each species of animal.

[5]Another approach would be to estimate opportunity cost using an integral of weight times value over the entire 4 months of grazing, discounted back to the beginning of the grazing season. It is not expected this approach would change the results greatly.

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Net benefits associated with wildlife in this analysis were defined as benefits accruing to the recreational hunter minus costs of hunting, i.e., net willingness to pay for hunting.[6] As wildlife numbers change in a particular hunt area, wildlife management agencies often adjust the number of permits offered, the type of animal that can be taken (e.g., male or female) and/or the length of hunting season. As herd size decreases, the opportunity for a recreational user to experience the activity is decreased. Loomis (1993) states that the loss of a recreation site or changes in recreation quality to a recreational user represent a change in consumer surplus for that user.

Consumer surplus is an appropriate representation of value when goods such as wildlife are not efficiently price rationed (i.e., not sold in markets) (McCollum et al. 1992). This type of value is appropriate for economic efficiency analyses which illustrate tradeoffs made under alternative policies. Expenditures are more correctly used when considering economic impact or equity issues. Consumer surplus estimates therefore were used to determine economic values for wildlife species in this analysis.

There is controversy in the literature concerning estimates of consumer surplus for wildlife. This debate centers around issues such as type of methodology used, accuracy of the methodology, recreation quality and what these estimates actually measure (Keith and Lyon 1985, Cory and Martin 1985, Cory et al. 1988, Bergstrom and Stoll 1989, Fried et al. 1995). Continued theoretical, analytical, and empirical analyses are needed to address many of the issues raised in the literature. While these issues are beyond the scope and purpose of this article, it is important to remember that economic values associated with wildlife are subject to limitations. Those limitations should be recognized when such values are used in applied analyses.

[6]It is likely there are other benefits associated with wildlife than just hunting opportunity such as viewing and existence benefits (Cory et al. 1988). Consumer surplus for a hunting trip includes all the attendant goods of the trip and does not value just the animal. Unfortunately, more accurate estimates of the value of the animal were unavailable. Thus, net benefits as defined in this analysis should be viewed as an inception.

Table 2. Number of animals[a] estimated for different levels of wild horses.

Animal Species	Scenario 1	2	3	4	5
	(Number of head)				
Wild Horses	0	128	184	196	241
Steers	2,809	2,360	2,173	2,162	2,159
Elk	300	300	300	300	0
Mule deer	830	740	586	300	0
Antelope	1,200	1,199	1,199	856	133

[a]Constrained by assumption of limiting forage consumption to 50% of current annual growth.

The 2 principle methods currently used to estimate consumer surplus are the Contingent Valuation Method (CVM) and the Travel Cost Method (TCM). The TCM uses observed behavior to estimate consumer surplus. The CVM tries to elicit an individual's willingness to pay (WTP) for a specified change or willingness to accept (WTA) a given change in dollar amounts (Randall 1987).

Because hunting is the primary recreational use of the allotment, value estimates from hunters were reviewed as published in Sorg and Loomis (1984) to obtain regionally relevant values for wildlife. Hansen (1977) was the only reported study that estimated values for deer, antelope, and elk hunting in the Intermountain region. Hansen (1977) utilized CVM to derive values for antelope, deer and elk based on a mail survey sent to a sample of 1975 U.S. Fish and Wildlife Service Hunting and Fishing Survey respondents. Survey participants were asked how much more they would be willing to spend before not engaging in the particular hunting activity in question (i.e., at what cost above the current trip cost would they quit hunting). This yielded an estimate of net willingness to pay or consumer surplus for the hunting trip. The mail survey format was noniterative and open-ended.[7] The following user day values, as adjusted by Sorg and Loomis (1984) to 1982 dollars, were used: deer hunting, $33.03 per hunter day; elk hunting, $36.37 per hunter day; and antelope hunting, $18.81 per hunter day.

[7]Current CVM methodology uses a dichotomous choice, or take it or leave it approach, to address perceived problems with the open ended noniterative methodoloty used by Hansen (1977). Additionally, the values estimated by Hansen (1977) do not account for changes in recreational quality which may occur as herd populations change, nor do they estimate possible existence values associated with these species. These values should therefore be viewed only as a starting point since they may not represent the true value of the wildlife.

As previously stated, the opportunity cost of foregone wildlife production in this analysis was defined as benefits to the recreational user associated with hunting minus the costs of hunting. Hansen's (1977) estimates of the net willingness to pay were used to obtain these estimates. Each of Hansen's (1977) hunter day values were multiplied by an estimated permit factor and by the average number of days per hunt for each species in Wyoming during 1994 (deer, 8.6 days; elk, 13.5 days; antelope, 2.2 days (Wyoming Game and Fish Department, 1995)). The permit factor equaled licenses sold divided by population of the species. The consumer surplus for the hunt only is realized if the hunter draws a permit; thus, a particular herd size does not provide as many permits as there are animals. The total adjustment to Hansen's (1977) net willingness to pay values ($/day * days/hunt * (# licenses/ # animals)) provided an estimate of the average consumer surplus for a hunting trip on a per animal basis. The resulting consumer surplus value may be a conservative estimate of wildlife as it does not account for non-consumptive values. The resulting economic values used in the analysis were $60.50 per deer, $285.76 per elk, and $18.83 per antelope.[8]

[8]These values were held constant while estimating opportunity costs associated with the different horse population scenarios and therefore do not capture the likely increase in marginal value of wildlife as that species becomes scarce on the allotment.

Results

Five different scenarios of animal production were estimated. The first scenario was the zero horse scenario. This baseline scenario, reported in Table 2, estimated the number of cattle, elk, deer, and antelope that could be produced on the allotment allowing no horses in the solution, assuming 50% forage utilization and constraining wildlife at greater-than-or-equal-to the minimum numbers previously specified (300 elk, 300 mule deer, and 700 antelope). Wildlife entered the solution at or near the maximum target levels specified in the AMP except for antelope. Antelope entered the solution at 300 head above their maximum target level of 900. This result was likely due to the take half-leave half assumption being applied to shrubs whereas some authors have suggested that actual shrub use in a sagebrush dominated area will be less than 50% for antelope and sheep (Severson et al. 1980). The number of steers entering the solution was 2,809 head, or the maximum constraint of 8,427 AUMs (assuming 4 months of grazing and an average AUM coefficient of 0.75). This scenario provided the base from which the biological tradeoffs and opportunity costs were estimated for cattle, elk, deer, and antelope in the remaining 4 scenarios.

The second scenario constrained horses at the minimum target level of 128. The constraints for wildlife were again set at greater-than-or-equal-to the minimum levels and the steer constraint was set at greater-than-or-equal-to zero. These constraints were used to represent target goals for wildlife in the AMP, realizing that BLM managers would have a greater opportunity to change livestock use than wildlife numbers. Results in Table 2 indicate that the minimum horse scenario (128 horses) resulted in a reduction of 449 steers, a 90 head reduction in deer and a reduction of 1 antelope. Elk remained at the minimum level of 300 head. The estimated opportunity cost for this scenario was $11,189 (Table 3).

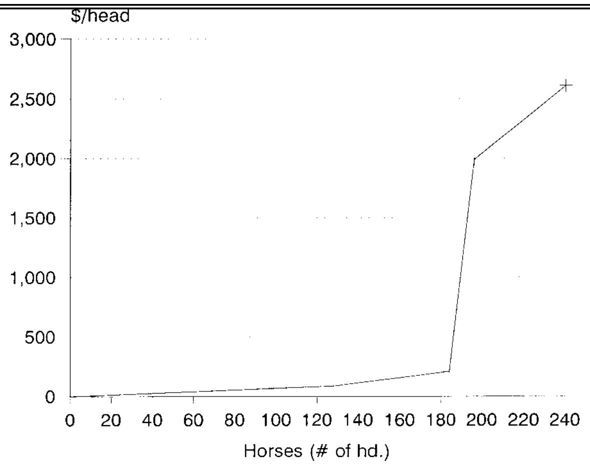

Fig. 1. Marginal opportunity cost of foregone wildlife and cattle production at various levels of wild horses.

The third scenario constrained horses at the median population level of 184 head. Wildlife constraints were less-than-or-equal-to the maximum target levels for deer and elk and 1,199 head for antelope. At this number of horses, steers were reduced 636 head compared to the solution with no horses, deer were reduced 244 head and antelope remained at 1,199 head. Optimal solutions for this and the second scenario came reasonably close to meeting target levels of wildlife and cattle months specified in the AMP. The opportunity cost associated with this third scenario was $22,890 (Table 3).

Table 3. Opportunity cost estimated for different levels of wild horses.[ab]

Animal Species	128	184	196	241
	($)			
Steers	5,725	8,109	8,249	8,288
Elk	0	0	0	85,728
Mule deer	5,445	14,762	32,065	50,215
Antelope	19	19	6,478	20,092
Total Cost	11,189	22,890	46,792	164,323

[a]At zero horses we assume opportunity costs of $0 for these species.
[b]Opportunity costs equal [(change in number of head from 0 horse scenario to horse number being examined) * estimated value per head], e.g., opportunity cost for mule deer at 128 horses is as follows: [(830–740) * $60.50]=$5,445.

An infeasible solution was obtained when attempting to maintain horses at the upper population levels of 225 and 375 head given a 50% forage utilization constraint. This suggests upper levels of wild horses could pressure the range resource to the extent that the goal of 50% utilization of key species could not be met given the other goals and constraints. Scenario 4, therefore, estimated the maximum feasible horse population when wildlife were constrained at greater-than-or-equal-to the minimum levels (300 elk, 300 mule deer, and 700 antelope), cattle were constrained at greater-than-or-equal-to zero and forage was constrained at 50% utilization. The number of horses was increased to 196 head before an infeasible solution was reached. At this horse population level, both elk and mule deer entered the solution at 300 head while 856 antelope entered the solution (Table 2). Steers numbered 2,162 head in this scenario, and the estimated opportunity cost was $46,792 (Table 3).

The next scenario examined the maximum number of horses that could occupy the allotment while maintaining 50% forage utilization, but allowing wildlife populations to fall below their minimum target levels. Thus, this scenario estimated the opportunity cost of foregone production of other animals when an agency managed for maximum horse numbers given a 50% forage utilization standard. The maxi-

Table 4. Illustration of forage usage at different levels of horses, wildlife and steers.

	Scenario							
Forage Category	A	B	C	D	E	F	G	H
	(Forage Usage as % of RHS constraint) [a]							
Spring grass/forbs	112	112	174	174	120	120	182	182
Summer grass/forbs	70	127	80	137	70	127	81	138
Fall grass/forbs	38	59	49	70	39	60	50	71
Winter grass/forbs	200	200	200	200	200	200	200	200
Spring shrubs	77	77	78	78	102	102	103	103
Summer shrubs	73	79	73	80	99	105	99	106
Fall shrubs	43	51	46	54	54	63	57	66
Winter shrubs	98	98	113	113	127	127	141	141

Scenario A- 225 horses, wildlife at minimum target levels, steers at minimum target level
Scenario B- 225 horses, wildlife at minimum target levels, steers at maximum target level
Scenario C- 375 horses, wildlife at minimum target levels, steers at minimum target level
Scenario D- 375 horses, wildlife at minimum target levels, steers at maximum target level
Scenario E- 225 horses, wildlife at maximum target levels, steers at minimum target level
Scenario F- 225 horses, wildlife at maximum target levels, steers at maximum target level
Scenario G- 375 horses, wildlife at maximum target levels, steers at minimum target level
Scenario H- 375 horses, wildlife at maximum target levels, steers at maximum target level
[a]RHS constraint is estimated to be 50% of current annual growth (a number over 100 represents consumption beyond take half-leave half).

mum wild horse population obtained from the solution, 241 head, was below the upper bound of 375 head. Elk and deer were eliminated from the solution and antelope were reduced to 133 head. The opportunity cost in this scenario was $164,323 (Table 3). Increasing horse numbers appeared to impact wildlife numbers to a greater extent than steer numbers. This was largely due to the assumptions about the grazing season for steers. This likely would not have been the case if steers were assumed to graze earlier in the season.

The AMP goals were fairly easy to maintain at the horse numbers used in the first 2 scenarios. The horse numbers estimated (196 and 241 head) in the last two scenarios represent the tradeoffs necessary to meet the 50% forage utilization goal. Competitive pressures associated with these upper levels of horses could force some animals to forage elsewhere, but it was beyond the scope of this study to predict how many would remain on the allotment. If animals were forced to forage off the allotment due to range deterioration, adjoining private lands could experience externalities as additional resources would be used by species other than livestock. This condition, at the very least, could create added conflicts for federal land managers.

The diet composition and habitat selection of wildlife could also change at these higher horse numbers (196 and 241 head). Additional data would be required to relax the constant diet assumption used in this model and to examine the effects of changes in diet composition. The literature indicates that high levels of horses cause reductions in wildlife numbers, stocking rates for cattle and decreases in range condition (Fisher 1983, Cook 1975), all of which are supported by these results.

Figure 1 represents the marginal opportunity cost per horse (change in total cost/change in horses). The graph illustrates that at horse levels above the median population target, marginal cost per horse increases well over $1,900. Solutions at these higher horse numbers approximate the tradeoffs required to meet the 50% forage utilization goal. The opportunity cost would probably be lower if the 50% forage utilization level were relaxed under higher horse production scenarios, but the range resource would likely be in danger of deterioration.

A forage consumption sensitivity analysis was estimated to illustrate possible effects higher horse numbers (225 and 375) might have on the range resource (Table 4). The 50% forage utilization constraint was omitted to accommodate higher horse populations. Grazing activities in the LP model were used to estimate forage utilization levels for each vegetation class and season under 8 different combinations of wild horses, wildlife, and steers. These combinations estimate forage consumption by class and season of use at upper levels of wild horses (225 and 375) and the minimum and maximum target levels of wildlife and steers. Utilization numbers reported for each combination are expressed as a percent of the right hand side values of each forage class by season under the take half-leave half assumptions. Therefore, numbers greater than 100 represent consumption beyond the conserving 50% utilization goal.

Results in Table 4 indicate spring grass would be utilized above the 50% rate for all scenarios. Additionally, winter grasses and shrubs were used heavily in all the scenarios. The increased competition for spring and winter forage at higher horse populations was expected given the dietary overlap suggested in Table 1. Results also suggest that if wildlife, cattle, and wild horse numbers are at their maximum, the range resource is at risk of deterioration. Results indicate that the primary tradeoffs made at higher horse numbers are at the expense of wildlife numbers and/or forage productivity.

Discussion and Conclusions

Opposing public views concerning the management of wild horses exist. Wild horse and burro advocates generally favor high population densities of feral horses and burros while livestock producers and wildlife interests generally do not (Williams 1985). This analysis used a case study approach to illustrate biological tradeoffs and opportunity costs of foregone wildlife and cattle production associated with the current wild horse program. Results for the case study area indicate costs associated with foregone wildlife and cattle production were lower at the minimum and median target horse numbers outlined in the allotment management plan. Marginal opportunity costs associated with horse numbers beyond those levels were well over $1,900 per horse (Fig. 1). Additionally, forage consumption estimates indicate the range resource could face deterioration at maximum wild horse population levels as specified in the AMP or based on recent historical levels (225 and 375 head) when minimum and maximum target numbers of wildlife and steers also graze the allotment.

The BLM is faced with managing public rangelands given legislative mandates that require sustained wild horse populations, multiple use, and sustained yield of the forage resource. Results of this analysis suggest viable wild horse populations could be maintained and much lower opportunity costs of foregone wildlife and cattle production would be realized, if the BLM were able to remove wild horses in a timely fashion. Certain barriers exist to this process and the costs associated with more timely roundups and adoptions would likely be higher.

Economic efficiency implies the resource base should be managed to maximize social welfare regardless of the distribution of benefits or income derived from that resource. To say that lower levels of horses would represent a more economically efficient allocation of the range resource without estimating the economic benefits associated with wild horses would be unjustified. Economic efficiency dictates that wild horses should be added or removed until the marginal benefits equal the marginal costs. Allocating the range solely on efficiency could create equity issues for some users or groups, e.g., distribution of benefits and compensation of individuals for loss due to infringement.

This study estimated the opportunity costs associated with foregone production, and while this is an important component of a benefit cost analysis, conclusions concerning economic efficiency cannot be drawn. The results and conclusions of this analysis are consistent with the institutional framework faced by BLM managers and the conclusions of Huffaker et al. (1990) concerning public range allocation. Estimates of opportunity costs at the higher levels of wild horses should be viewed cautiously given the limitations of the data. Cost estimates at the higher levels of wild horses are particularly limited since they are based on hypothetical tradeoffs required to achieve a 50% forage utilization. Realistically, wildlife numbers would most likely be greater than those estimated. Wildlife would not be expected to change forage consumption patterns or habitat selection unless grazing conditions deteriorated significantly. Moreover, behavioral aspects of the interactions between wild horses and other species could affect these patterns as well.

This analysis provides an illustration of the data required to complete part of the benefit-cost analysis as proposed by Hyde (1978). Unfortunately, the data limitations given current research require several assumptions that were limiting at best in explaining real world trade-offs associated with wild horses. The analysis proposed by Hyde (1978) would require more accurate estimates of wildlife values, better biological data to more accurately estimate marginal substitution rates as forage consumption patterns and diets change with populations of animals, and data that would facilitate a dynamic modeling of interactions between wild horses and other species.

Economic analyses of wild horses are sparse. It is hoped this study will stimulate further economic work along the lines proposed by Hyde (1978). Only when all the costs and benefits associated with wild horses are estimated can the issue of economic efficiency concerning wild horses and public resource allocation be fully addressed.

Literature Cited

Bastian, C.T. 1995. Average prices of cattle and calves: eastern Wyoming and western Nebraska, 1990–1994. Bull. AE95-2. Dept. Agr. Econ. Univ. of Wyoming. Laramie, Wyo.

Bastian, C.T., J.J. Jacobs, L.J. Held, and M.A. Smith. 1991. Multiple use of public rangeland: antelope and stocker cattle in Wyoming. J. Range Manage. 44:390–394.

Bergstrom, J.C. and J.R. Stoll. 1989. Application of experimental economics concepts and precepts to CVM field survey procedures. Western J. Agr. Econ. 14:98–109.

Bureau of Land Management (BLM). 1990. Draft outline for Whiskey Peak complex allotment management plan. USDI, BLM Rock Springs District, Wyo.

Clary, W.P. 1983. Interfacing physical data and economics, p. 115–119. *In:* Proc. Range economics symposium and workshop. F.J. Wagstaff (comp.). USDA Forest Serv., Intermountain Region. Ogden, Utah. Gen. Tech. Rep. INT-149.

Cook, C.W. 1975. Wild horses & burros: a new management problem. Rangeman's J. 2:19–21.

Cory, D.C. and W.E. Martin. 1985. Valuing wildlife for efficient multiple use: elk versus cattle. Western J. Agr. Econ. 10:282–293.

Cory, D.C., B.D. Colby, and E.H. Carpenter. 1988. Uncertain recreation quality and wildlife valuation: are conventional benefit measures adequate? Western J. Agr. Econ. 13:153–162.

Crane, K.K., M.A. Smith, and D. Reynolds. 1997. Habitat selection patterns of feral horses in southcentral Wyoming. J. Range Manage. 50:374–380.

Denniston, R.H., M. Boyce, W.D. McCort, J. Timmerman, B. Holz, and L. Wollrab. 1982. Feral horse study: habitat preference and use. Univ. of Wyoming Dep. of Zool. and Physio. Report to USDI-BLM Contract AA85-CTO-31.

Eberhardt, L.L., A.K. Majorowicz, and J.A. Wilcox. 1982. Apparent rates of increase for two feral horse herds. J. Wildl. Manage. 46:367-374.

Ensminger, M.E. and C.G. Olentine, Jr. 1978. Feeds and nutrition- abridged. Ensminger Publ. Co., Clovis, Calif.

Fisher, C. 1983. The wild horse dilemma: background, prospective, and action. Rangelands 5:164–166.

Fried, B.M., R.M. Adams, R.P. Berrens, and O. Bergland. 1995. Willingness to pay for a change in elk hunting quality. Wildl. Soc. Bull. 23:680–686.

Godfrey, E.B. 1979. The wild horse laws. Utah Sci. 40(2):45–50.

Godfrey, E.B. 1983. Economics and multiple use management on federal rangelands, p. 77–81. *In:* Proc. Range economics symposium and workshop. F.J. Wagstaff (comp.). USDA Forest Serv., Intermountain Region. Ogden, Utah. Gen. Tech. Rep. INT-149.

Godfrey, E.B. and P. Lawson. 1986. Wild horse management: an economic perspective. J. Equine Vet. Sci. 6:266–272.

Hansen, C. 1977. A report on the value of wildlife. USDA Forest Serv., Intermountain Region. Ogden, Utah.

Holecheck, J.L. 1988. An approach for setting the stocking rate. Rangelands 10:10–14.

Huffaker, R.G., J.E. Wilen, and B.D. Gardner. 1990. A bioeconomic livestock/wild horse trade-off mechanism for conserving public rangeland vegetation. Western J. Agr. Econ. 15:73–82.

Hyde, W.F. 1978. Wild horses and allocation of public resources. Rangeman's J. 5:75–77.

Kearl, W.G. 1990. Average prices of cattle and calves: eastern Wyoming and western Nebraska, 1985-1989. Bull. AE90-2. Dept. Agr. Econ. Univ. of Wyoming. Laramie, Wyo.

Keith, J.E. and K.S. Lyon. 1985. Valuing wildlife management: a Utah deer herd. Western. J. Agr. Econ. 10:216–222.

Krysl, L.J., M.E. Hubbert, B.F. Sowell, G.E. Plumb, T.K. Jewett, M.A. Smith, and J.W. Waggoner. 1984. Horses and cattle grazing in the Wyoming Red Desert I, food habits, and dietary overlap. J. Range Manage. 37:72–76.

Loomis, J.B. 1993. Integrated public lands management: principles and applications to national forests, parks, wildlife refuges, and BLM lands. Columbia Univ. Press, New York.

Martner, B.E. 1986. Wyoming climate atlas. Univ. Neb. Press., Lincoln, Nebr.

McInnis, M.L., and M. Vavra. 1987. Dietary relationships among feral horses, cattle and pronghorn in southeastern Oregon. J. Range Manage. 40:60–66.

McCollum, D.W., G.L. Peterson, and C. Sorg-Swanson. 1992. A manager's guide to the valuation of nonmarket resources: what do you really want to know? p. 25–52. *In:* G.L. Peterson, C. Sorg-Swanson, D.W. McCollum, and M.H. Thomas (eds.), Valuing wildlife resources in Alaska. Westview Press, Boulder, Colo.

Medcraft, J.R. and W.R. Clark. 1986. Big game habitat use and diets on a surface mine in northeastern Wyoming. J. Wildl. Manage. 50:135–142.

Miller, R. 1983. Habitat use of feral horses and cattle in Wyoming's Red Desert. J. Range Manage. 36:195–199.

Nack, W. 1988. Bad time for wild horses. Sports Illus. Time, Inc. New York. April. pp:28–35.

Olsen, F.W. and R.M. Hansen. 1977. Food relations of wild free-roaming horses to livestock and big game, Red Desert, Wyoming. J. Range Manage. 30:17–20.

Randall, A. 1987. Resource economics: An economic approach to natural resource and environmental policy. John Wiley & Son, New York.

Rittenhouse, L.R., D.E. Johnson, and M.M. Borman. 1982. A study of food consumption rates and nutrition of horses and cattle. Final report of the BLM. USDI. Washington, D.C.

Salter, R.E. and R.J. Hudson. 1980. Range Relationships of Feral Horses with Wild Ungulates and Cattle in Western Alberta. J. Range Manage. 33:266–271.

Severson, K.E., M. May, and W. Hepworth. 1980. Food preferences, carrying capacities and forage competition between antelope and domestic sheep in Wyoming's red desert. Univ. of Wyoming Agr. Exp. Sta. SM-10. Laramie.

Smith, M.A., B.F. Sowell, L.J. Krysl, G.E. Plumb, M.E. Hubbert, J.W. Waggoner, and T.K. Jewett. 1982. Vegetation utilization, diets, and estimated dietary quality of horses and cattle grazing in the Red Desert of westcentral Wyoming. Univ. of Wyoming Dept. of Range Manage. BLM contract No. AA851-CTO-31.USDI. Washington, D.C.

Sorg, C.F. and J.P. Loomis. 1984. Empirical estimates of amenity forest values: a comparative review. Gen. Tech. Rep. RM-107, USDA, Forest Serv., Rocky Mountain Forest and Range Exp. Sta., Ft. Collins, Colo.

Sundstrom, C., W.G. Hepworth, and K.L. Diem. 1973. Abundance, distribution and food habits of the pronghorn (a partial characterization of the optimum pronghorn habitat). Bull. 12 Wyoming Game and Fish Commission, Cheyenne, Wyo.

Torell, L.A., L.W. VanTassell, N.R. Rimbey, E.T. Bartlett, T. Bagwell, P. Burgener, and J. Coen. 1995. The value of public land forage and the implications for grazing fee policy. Agr. Exp. Sta. Bull. 767. New Mexico State Univ.

U.S. Department of Agriculture/Natural Resources Conservation Service (USDA/NRCS). 1990. Technician's guide to range sites and range condition. Wyoming section. Major Land Resource Area 34.

Williams, T. 1985. Horses, asses, and asininities. Audobon. September. pp:20–23.

Wyoming Game and Fish Department. 1995. Annual report. Cheyenne, Wyo.