Comparing the economic value of forage on public lands for wildlife and livestock

JOHN LOOMIS, DENNIS DONNELLY, AND CINDY SORG-SWANSON

Abstract

Deciding how to allocate forage among animals is a fundamentally important process in range management. The wisdom of these decisions can be enhanced by estimating the marginal value of forage needed by competing species. We present a method for obtaining such estimates and apply this method to generate net economic values of forage for elk and deer in Challis, Idaho. Specifically, a demand curve derived using a regional travel cost model is used to statistically estimate the marginal value of wildlife and forage. Comparisons of the value of forage to livestock and wildlife indicate equivalent values in the Challis, Idaho, area for these 2 uses.

Key Words: benefit-cost analysis, economic efficiency, marginal value, big game wildlife, elk, deer

On many tracts of public lands there is some degree of competition between domestic livestock and wildlife. Economically efficient use of these public rangelands requires adjusting the mix of livestock and wildlife such that the mixture is roughly proportional to the relative values these different animals provide. Often more wildlife and livestock can be accommodated by boosting range productivity through investments such as water developments and manipulation of the vegetation. However, the U.S. Office of Management and Budget and some economists (Stroup and Baden 1983:48) are skeptical about the returns to these investments.

In response to the scrutiny that its rangeland investments were receiving from economists and environmental groups, the Bureau of Land Management (BLM) developed a model called SAGE-RAM. This model is used to perform benefit-cost analysis on resource investments including livestock and wildlife (U.S. Bureau of Land Management 1985). As part of its overall Forest Planning effort, the U.S. Forest Service is using a large scale linear programming model called FORPLAN to evaluate its resource tradeoffs, including livestock grazing (Johnson et al. 1982). Although these models are useful, their analytical capabilities are limited by difficulty in estimating marginal values of wildlife and forage used by wildlife in a manner commensurate with livestock forage values (See Godfrey 1982; Bartlett 1982, 1984; Dyer 1984).

Marginal values of elk and deer on public lands are rarely estimated (Cory and Martin 1985, Keith and Lyon 1985). Cory and Martin use the Contingent Value Method for determining the marginal value per elk. Keith and Lyon use a household production function (hedonic) approach within an optimal control framework to estimate a marginal value per deer. Their approach develops a dynamic bio-economic model.

In contrast to previous research, we use the travel cost method (TCM) to estimate marginal values of 2 big game species (elk and deer) and calculate the marginal value product of an animal unit month (AUM) of forage to these species. Comparisons of the marginal value of forage between wildlife and cattle and between different big game species are made. Like Cory-Martin, our model is not dynamic but does capture simple bio-economic production relationships between harvest, big game populations, and habitat.

Methods

Marginal Valuation of Wildlife with Travel Cost Method

The economic value of any good or service is defined as consumers' or producers' net willingness to pay (Freeman 1979). Measuring consumers' net willingness to pay (WTP) involves measuring the area under their demand curve. Because the travel cost method estimates the demand curve for recreation, the willingness to pay for recreation under existing conditions can be calculated. Maler (1974) first developed the theoretical conditions which must be met to use the travel cost method for valuing *changes* in environmental quality. Drawing on Maler's (1974) concept of "weak complementarity" between a private good (travel) and a public good (environmental quality), Freeman (1979:196-214) discusses alternative ways in which the travel cost method can be used to estimate

Authors are assistant professor, Division of Environmental Studies and Department of Agricultural Economics, University of California-Davis, Davis 95616; and research forester and research wildlife biologist, Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service, Fort Collins, Colo.
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the benefits of improved conditions at a recreation site. For example, consider an ordinary demand equation for a recreation site of the following form:

$$V = h(P,Q,Y) \tag{1}$$

where: V = visits, P = price, Q = site quality and Y = income.

Weak complementarity allows us to state the benefits (i.e., net WTP) of improving site quality from Qo to Q1 as:

$$\text{Net WTP}(Q1 - Qo) = \int_{Po}^{P2} h(P,Q1,Y)dP - \int_{Po}^{P1} h(P,Qo,Y)dP \tag{2}$$

where P1 and P2 drive visits to zero for demand curves associated with the current and improved level of quality, respectively, and Po is the current price. The marginal (incremental) value of a harvested animal is the ratio of the increase in net WTP (Eq. 2) to the increment of animals harvested associated with moving from Qo to Q1.

Empirical estimation of a demand function with a variable for quality is not possible when estimating a demand curve for just 1 site because there is no variation in site quality across visitors. Freeman (1979:212) suggested a 2-step process for pooling data across sites to estimate a coefficient on site quality. Later Vaughan and Russell (1982:453) demonstrated how to estimate a coefficient on quality using 1 equation of the following form:

$$Vij = B_0 - B_1TCij + B_2Qj + B_3(TCij * Qj) + \ldots B_{n-1}Zij + B_n(Zij * Qj) \tag{3}$$

Where: Vij = visits by individual i to site j, i = 1,...t and j= 1,...s
TCij = transportation and time costs of individual i to site j
Qj = a measure or index of site j's quality
Zij = other variables including price of substitutes, demographics of recreationists, etc.

Equation 3 presents the full interaction model where site quality is assumed to affect all of the other variables (Vaughan and Russell 1982:453). Whether the quality variable affects all of the other variables is a testable hypothesis. A similar approach was developed earlier by Knetsch, et al. (1976). The varying parameter model allows for pooling of visitation data across many sites. If these sites have sufficient variation in site quality, then the analyst will be able to estimate coefficients that predict how visitation will change with changes in site quality. As such, a new second stage site demand curve is estimated for each site under improved site conditions. As discussed above, the area between these curves is the incremental (marginal) benefits attributable to that improvement.

Data Sources

The state of Idaho provides a good opportunity to compare wildlife forage values to that of cattle. Idaho is a state with over two thirds of its land in public ownership. A survey of persons hunting in Idaho in 1982 was performed to collect the necessary data for this model. The sampling frame was any resident or nonresident having a valid Idaho hunting license. To insure the assumptions of TCM were met, only hunters stating that hunting was the primary trip purpose and that hunt unit was the primary destination were included in the analysis. The elk hunting survey contacted, via telephone, 2.1% of licensed elk hunters for a total sample of 1,629 elk hunters during January–February 1983 regarding the 1982 hunting season (Sorg and Nelson 1986). The deer hunting survey contacted 0.917% of licensed deer hunters for 1,445 deer hunters during January–February 1983 regarding their 1982 hunting season (Donnelly and Nelson 1986). Data were collected on hunter expenditures, travel distances, success, days afield and other trip characteristics. Unfortunately, interviewers were not allowed to collect data on individual hunter income and other demographic characteristics of hunters.

Demand Model

A zonal or aggregate travel cost model is estimated for several reasons. In terms of structure, using trips per capita reflects both the quantity of trips consumed by current hunters and also the probability of participation in hunting at site j. This form of the dependent variable adjusts for several problems that arise when estimating an individual observation TCM demand model with ordinary least squares regression: (1) censoring and truncation of the data due to omission of observations of hunters who did not hunt at the particular area j; (2) entry of new hunters visiting site j under improved hunt quality at site j. While separate estimation of these 2 components of total trips is sometimes desirable, data limitations preclude such a solution here. In addition the survey did not include individual specific data on explanatory variables such as income. As noted by Brown et al. 1983, the zonal TCM model also minimizes the effect of recall of trip distances on estimated coefficients.

It was desirable to estimate both elk and deer demand equations using the double log demand model. This functional form produces a diminishing marginal value per animal when the coefficient on harvest is less than one. However, we could not estimate this functional form with the full interaction model. As specified in equation 3, this model had very high multicolinearity due to presence of the interaction terms. This resulted in a near singular matrix. The simplified model proposed in this study for elk and deer is thus closer to a pooled multi-site demand equation. The resulting model is:

$$\ln(Vij/POPi) = BO - Bl(\ln DISTij) +- B2(\ln INCi) + B3(\ln THVSTj) \tag{4}$$

Where: VIJ = hunter trips from origin i to site j
POPi = county i's population, i = 1,...95 for elk, i=1,...64 for deer
DISTij = round trip distance from origin i to site j.
INCi = county i's per capita income
THVSTj = total hunt unit harvest of respective species at site j, where j=1,...63 for elk and j = 1,...78 for deer.

Because the quality variable is total site harvest, the possibility exists that this variable is endogenous in a time dependent bioeconomic system. Even though the dependent variable is trips *per capita* from each origin to site j rather than total trips to site j, simultaneity may be present. In particular, the demand equation in equation (4) may be part of a 2 equation bio-economic system. Equations 4–5 show one such system:

$$\ln(Vij/POPi) = BO - B1(\ln DISTij) + B2(\ln INCi) + B3(\ln THVSTj) \tag{4}$$

$$\ln(THVSTj) = AO + A1(\ln APOPjt\text{-}1) + A2(\ln Vij/POPi) + A3(\ln HAj) + A4(\ln THABj) \tag{5}$$

where: APOPjt-1 = Elk or deer populations at site j in time t-1
HAJ = Huntability of site j in terms of terrain, denseness of vegetation, etc.
THABj = Total habitat in site j measured in square miles.

All over variables are as defined earlier.

However, data is not available for all of the variables in this system and therefore equation 4 is estimated using two-stage least squares. Because data is available on the exogenous variable THABj and APOPjt-1 as well as DISTij and INCi, the order condition for equation 4 is met for both deer and elk. In essence, our application of two-stage least squares involves regressing

THVST on all the exogenous variables in equations 4 and 5 (except HA for which no data is available) and then using the predicted values of THVST when estimating equation 4.

The demand curve in equation 4 uses distance as the price variable. The area under this demand curve but above the current travel distance (equation 2) is net willingness to pay in added miles. Therefore, we must convert the resulting willingness to pay in miles to dollars. This translation requires estimates of transportation costs plus the value of travel time. Travel distances are converted to dollars using the average transportation cost of $0.31 per vehicle mile reported by elk hunters and $0.183 per vehicle mile of deer hunters. These figures are divided by the average number of hunters per vehicle to arrive at transportation cost per mile per hunter. Travel time is valued at one-third of the wage rate, the mid point in Cesario's (1976) survey of transportation planning literature. While Smith et al. (1983) questions the use of a fraction of the wage rate rather than the entire wage rate other analyses of recreation travel behavior support use of a fraction of the wage rate (McConnell and Strand 1981). Recent empirical results for deer hunting in Wisconsin by McCollum, Bishop and Welsh (personal communication) provide strong support for a value of travel time between 20% and 33% of the wage rate.

Calculating Marginal Productivity of Forage

To calculate the marginal value product of the forage in producing elk requires site specific knowledge of the production relationships. Hunt areas 36 and 36B in the Challis, Idaho, area were selected to calculate site specific production relationships and marginal values of elk and deer for this study. The Challis area was designated by the Natural Resources Defense Council vs Morton court decision as the area for Bureau of Land Management's first Grazing Environmental Impact Statement (EIS). The Challis area has been the scene of substantial controversy over grazing versus wildlife prior to, during and after the preparation of the EIS (Nelson 1980). BLM's Final EIS (U.S. Bureau of Land Management 1977: Chap 3:21) states that during May and June there is spatial and dietary competition for grasses between cattle and antelope, deer and elk in the area. Elk and cattle have strong dietary similarities (particularly in the spring) in terms of their preferences for consuming grasses. Therefore the potential dietary competition from increasing elk or cattle populations may be the greatest. There also exists substantial evidence of social avoidance of cattle by elk, with presence of cattle (and associated humans tending the livestock) causing elk to leave an area of otherwise desirable habitat (Lyon 1985:17; Nelson 1984).

Because there is still some debate about the exact form and extent of competition between cattle and elk in general and specifically in the Challis area, no attempt is made to establish an explicit production possibilities curve in this paper (see Nelson 1984, Cory and Martin 1985 for attempts in other areas). Rather we will analyze the incremental values of wildlife and forage for likely increases in wildlife numbers. This increase in wildlife involves costs in terms of either reduced cattle numbers or capital investment to increase range productivity.

BLM's Final EIS states that at least a 30% increase in deer is sustainable with additional forage. This figure is consistent with Idaho State Department of Fish and Game's objectives for deer herds in those units (U.S. Bureau of Land Management 1977, Chap 3:27). The potential for increased carrying capacity of elk habitat due to new grazing systems is about 20% (U.S. Bureau of Land Management 1977, Chap 3:29). Although there are many important components of habitat for elk and deer in the Challis area, forage on winter and spring ranges appears to be limiting populations in the Challis area. The purpose of these estimates is to provide a benchmark of what the potential improved condition might be. The remaining analysis calculates marginal values of wildlife and forage using current harvest and a 25% increase in elk and deer populations that results from range improvements and better grazing practices such a sequential rest-graze systems.

A 25% increase in elk harvest in unit 36 requires 28 more bull elk. According to information provided by the Idaho Fish and Game (Parker, personal communication) production of 28 more bull elk for harvest (surplus production) annually would require the elk herd in unit 36 increase by a total of 378 elk. The composition of the increase is 19% bulls, 54% cows and 27% calves. The available literature (Bureau of Land Management 1977: 1-2; Thomas 1984) suggests that each adult elk consumes between 0.4 and 0.67 AUM's of forage each month. Our analysis uses the average of these 2 estimates or 0.54 AUM's per adult elk and half this amount per calf. This latter information is combined with the herd structure to generate a simple production relationship relating the number of elk available for harvest to quantity of forage. Using unit 36 to illustrate the calculations, the relationship is:

$$EH = 1/[(9.85AE^{*}.54AUM^{*}12months)+(3.65CE^{*}.27AUM^{*}12months)] \quad (6)$$

where: EH = bull elk available for harvest
AE = adult elk (bulls and cows),
CE = calf elk
AUM = Animal Unit Month of forage

Carrying out the calculations in equation (6) yields the simple elk-forage relationship for Unit 36 of:

$$EH = 0.0132AUM \quad (7)$$

If instead of using .54 as the AUM's required by an elk, one uses the .4 of Thomas or the .67 value of BLM, the resulting production relationship would be .0178AUM and .010AUM, respectively. The implications of these differences are discussed in the results section.

For unit 36B the elk-forage relationship is:

$$EH=1/[10.22AE^{*}.54AUM^{*}12months)+(3.78CE^{*}.27AUM^{*}12months)]$$
=.0127AUM, with a range of .01AUM to .017AUM if .4 and .67 AUM's per elk are used. (8)

The simple deer forage relationship for unit 36 is:

$$DH=1/[(6.935AD^{*}.25AUM^{*}12months)+(2.565F^{*}.12AUM^{*}12months)] =0.0408AUM \quad (9)$$

Where: DH = deer harvested
AD = adult deer
F = fawn
AUM = Animal Unit Month of forage

If instead of .25AUM's per deer from U.S. Bureau of Land Management (1977) one uses .2AUM's per deer (Thomas 1984) in equation 9, the deer-forage relationship becomes DH=.05AUM instead.

For unit 36B the simple deer-forage relationship is:

$DH=1/[(5.548AD^{*}.25AUM^{*}12months)+(2.052F^{*}.12AUM^{*}12 months)]=.051AUM$. Using .2AUM instead of .25AUM makes the forage relationship DH=.063AUM.

Results

Estimated Demand Equations

The elk TCM demand equation estimated using the two stage least squares procedure described above is shown in equation 11:

$$\ln(Vij/POPi)=24.173 -1.629(\ln DISTij) -3.126(\ln INCi)+0.431(\ln THVSTj)$$
T values (20.85) (-30.28) (-24.09) (5.51) (11)

The R^2 was 0.74 and the F value was 526. All of the individual coefficients and the F value are significant at the 1% level. The size of the F values and t statistics shows the double log functional form offers a good explanation of the relationships between the variables.

The negative sign on income may at first appear somewhat counterintuitive. It may be a result of using county per capita income instead of individual hunters income (which was not available). Mendelsohn (1984:98) found a statistically significant negative relationship between number of trips and income even when using primary data on deer hunter income. When dealing with time intensive activities such as hunting, it may be that higher income measures the greater cost of time foregone when hunting. Thus, the negative sign on income reflects a price coefficient for onsite time costs rather than ability to pay in the traditional use of money income. Alternatively, higher income hunters may substitute fewer longer trips for more frequent shorter trips.

The deer demand equations estimated using the two-stage least squares procedures described above is:

$$\ln(Vij/POPi)=47.19 \; -0.649(\ln DISTij) \; -6.381(\ln INCi)+0.327(\ln THVSTj) \quad (12)$$

T values (11.33) (−11.88) (−13.14) (2.21)

The R^2 was 0.47 and the F value was 160. The distance and income coefficients and the F value are significant at the 1% level. The harvest variable is significant at the 5% level. It was not possible to include a statistically significant variable to reflect the price or quality of substitutes in either the elk or deer equations.

Calculation of Marginal Values

In unit 36, a 25% increase in bull elk harvest (28 more), generates a rightward shift in the elk hunting demand curve. The area between the new and old curves for Unit 36 is an increase in net economic benefits of $14,075, annually. The marginal value of a harvested bull elk is $502. The marginal value per elk and deer in Unit 36B is $647 and $310, respectively. Table 1 displays marginal values per animal under current and improved conditions.

Table 1. Marginal values (MV) of wildlife in Challis, Idaho.

	Current herd sizes			Twenty-five percent increase in herd size		
	MV per animal Harvested	MVP per AUM		MV per animal harvested	MVP per AUM	
Unit 36						
Elk	$535	$5.70	$9.55	$502	$5.35	$8.96
Deer	$167	$6.82	$8.47	$155	$6.32	$7.85
Unit 36B						
Elk	$685	$7.04	$11.78	$647	$6.65	$11.13
Deer	$333	$17.00	$21.11	$310	$15.81	$19.64

The values for deer in Table 1 are midway between what Keith and Lyon (1985) estimated for the marginal value of deer in Utah using a hedonic approach within an optimal control framework. Specifically, they estimated a value of $39.52 per deer in the herd. Using their percentage of the herd harvested figure of 16% yields a value of $247 per buck harvested. In terms of our elk results, the values in Table 1 are about one-half to one-third those estimated by Cory and Martin (1985) in Arizona using the Contingent Valuation Method. Their value of $106 per elk in the population translates to $1,162 to $1,484 per elk harvested. However, given the large excess demand for elk hunting permits in Arizona compared to the study area in Idaho, the higher value in Arizona is not suprising. Specifically, the 2 different elk hunts in Arizona saw 3,840 applicants for 400 permits and 3,277 applicants for 1,500 permits. In Idaho there is no excess demand for resident elk permits.

Combining the marginal product of forage calculated from equation 10 (.051) with the marginal value of a deer in unit 36B ($310) yields a value marginal product of $15.81 per AUM. The $15.81 represents the maximum amount hunters would bid per AUM for the increased forage to produce 25% more deer in hunt unit 36B. Calculation of the marginal value product for elk follows this same procedure used for deer. Table 1 presents marginal values per animal and per AUM for big game units 36 and 36B. Table 1 displays 2 estimates of marginal value product (MVP) of forage. The first is computed using BLM's deer/elk per AUM and the other reflecting Thomas' (1984) deer/elk per AUM figure.

Although marginal values per animal are higher for elk than deer, comparison of equations 8 and 10 reveal that a standardized AUM produces about 4 times as many harvestable deer as it does elk. This is reflected in the MVP figures. The large difference in forage value for deer in the 2 units relates to differences in marginal value per deer and the higher marginal productivity of Unit 36B in producing deer. Specifically, it takes only an increase of 7.6 deer to produce 1 more available for harvest in unit 36B compared to 9.5 deer to produce 1 more for harvest in unit 36 (Parker, personal communication). The higher marginal value per deer in Unit 36B appears to reflect the higher harvest rate in Unit 36B.

Economic Value of Livestock Forage

A variety of techniques can be used to estimate the value of public land forage to cattle ranchers. Acceptable methods include comparison with market priced forages, capitalization of permit values and production function techniques such as linear programming (Bartlett 1984). The joint U.S. Forest Service and Bureau of Land Management Appraisal Report (Tittman and Brownell 1984) states that fair market value of public land grazing in the region where Challis is located would be $7.60 per AUM. While the representativeness of the values in this report have been questioned (Obermiller, personal communication), it provides one estimate of forage value. Wilson, et al. (1985) use a linear programming approach with ranch budget data to estimate forage per AUM for the BLM land in the Challis area. The weighted average value of the forage across the 4 different size classes of ranches is $6.40 (where the weights are number of BLM AUM's used by each size class). However, the livestock value per AUM ranges from a low of $1.14 to a high of $10.10 in the 2 relevant areas studied by Wilson, et al. Unfortunately, a perfect overlay of the 2 hunting units and allotments is not possible in our current study.

Discussion and Conclusions

Comparison of the wildlife values in Table 1 with these forage values shows that deer and elk are economically competitive with cattle in the Challis, Idaho area. In particular, the marginal value of forage for wildlife in Unit 36B is quite a bit larger than livestock forage values. A more economically efficient mix of uses would involve providing additional forage to wildlife until the marginal value to wildlife decreased to the marginal value of forage to livestock. Because the functional form of the demand equations we estimate have the property of diminishing marginal value for each additional animal, in theory, one can calculate the increase in wildlife herd size necessary to drive forage values down into equilibrium with livestock. Such "fine tuning" requires more precision in estimates of economic values and production relationships than is present in this study. For the time being, the existing divergence in values of forage between wildlife and livestock in unit 36B shows the direction that resource management should be moving from an economic efficiency standpoint.

Another implication of these results relates to the variation in values of livestock forage relative to wildlife. A few combinations of ranch sizes and allotments have very low values for livestock forage in the range of $1.14 to $3.09. In these areas, elk and deer values would tend to dominate livestock. From an economic efficiency standpoint wildlife habitat issues should have a major role in determining seasons of use, timing of livestock entry and exit from the range and optimal stocking levels. For other combinations of ranch sizes and allotments, livestock grazing values are quite competitive ($8.37 to $10.10 per AUM) with elk and deer forage values of $5.70 to $9.55 per AUM in unit 36. In these areas, both rancher/livestock needs and wildlife habitat concerns should influence seasons of use, timing of livestock entry and optimal stocking levels.

If greater geographical and statistical precision in estimating the value of forage to wildlife and livestock were possible, site specific recommendations could be made for modifying the allocation of forage between cattle and wildlife. For the time being these relative values per AUM at least provide information on which direction livestock and wildlife populations should be moving from an economic efficiency view point.

This paper also demonstrates that marginal values of wildlife and marginal value product of forage to wildlife can be developed with the travel cost method. The resulting values are commensurate with the values of forage to livestock and hence allow use of economic efficiency analysis in dealing with livestock-wildlife trade-offs. In addition, the wildlife values are useful for determining the economic feasibility of investments to increase forage production for wildlife. Incorporation of these more conceptually correct marginal values of wildlife and forage into BLM's SAGERAM and the U.S. Forest Service's FORPLAN models would improve the accuracy of these analytical aids in suggesting economically efficient use of public rangelands.

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