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Estimating the economic value of big game habitat production from prescribed fire using a time series approach

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Abstract

This paper demonstrates a time-series production technique to quantify the deer harvest and deer hunting benefits of controlled burns or prescribed fire. The time series regression model showed a statistically significant and positive effect of prescribed fire on deer harvest. The net economic value of the resulting additional deer hunting benefit was estimated using the Contingent Valuation Method at $ 98 per additional deer harvested. The initial deer hunting benefits of an additional 1,000 acres of prescribed burning are between $ 2,674 and $ 3,128 or $ 2–3 per acre. The costs of prescribed burning greatly exceed these benefits, suggesting that deer hunting benefits represent only a small part of the multiple use benefits of prescribed fire.

Key words: California, contingent valuation, deer, fire management, hunting, National Forests, wildlife.

Introduction

After decades of fire suppression where nearly every wildfire was immediately extinguished, forest management agencies have begun to recognize the benefits of fire to ecosystems, and specifically to habitat of several wildlife species. To reintroduce fire back into these ecosystems that have now accumulated an unnaturally high level of fuel in the form of underbrush and pine needles, a controlled burn or purposely set fire to reduce the fuel load is prescribed. Specifically, prescribed fires are low intensity fires set by forestry professionals, under controlled conditions (e. g., high humidity, low wind) to begin to restore a natural fire cycle whereby it will be safe to allow natural fire to occur. This research presents a statistical approach to evaluate the effectiveness of prescribed burning for increas-

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ing big game wildlife habitat as well as illustrating its application for the San Bernardino National Forest located in southern California. The methodological contribution begins to answer the challenge posed by Hesseln (2000) in her recent review of the economics of prescribed burning. She stated "... however, there is a lack of economic models to evaluate short- and long-term ecological benefits of prescribed fire. Without understanding the relationship between economic outcomes and ecological effects, it will be difficult to make effective investment decisions. Research should focus on defining a production function to identify long-term relationships between prescribed burning and ecological effects. Identifying production functions relationships will form the basis for future cost-benefit analysis with respect to prescribed burning." (Hesseln 2000: 331–332). This study suggests a methodology to estimate a production relationship between prescribed burning and deer harvest using time series data and applies it to a National Forest to demonstrate its practicality. This effort makes a first modest step in the direction suggested by Hesseln and the methodology could be used for evaluating other wildlife prescribed burning programs.

Thus the purpose of this study is to test whether prescribed burning has a systematic effect on deer harvest and estimate a monetary value of the additional deer harvest. The remainder of this paper is organized as follows: the next section specifies the deer harvest production function. Then details of the study area application are provided. Next, the production function is statistically estimated and used to simulate the increase in deer harvest with an increase in prescribed burning. This is followed by an economic analysis of the value of additional deer harvest. The last section combines the simulation and valuation results to estimate the deer hunting benefits of additional prescribed burning, which is then compared to the costs.

Production function modeling approach

Estimating a production function that relates deer harvest to acres of prescribed burning must also control for other factors that influence the production of deer for harvest. This includes wildfire, rainfall, temperature, deer population and hunter pressure or effort. Thus, multiple regression is an appropriate statistical technique. A time series approach is adopted so as to test the effects of fire, prescribed and wild, across the entire study area over an extended period of time.

USDA Forest Service fire records provided data from 1979 for wildfire and prescribed burns within the San Jacinto Ranger District (SJRD) of the San Bernadino National Forest. Annual deer harvest data from 1979 to 1998, was provided by California Department of Fish and Game (CDFG). The full model is given below in equation (1), which allows for harvest to be sensitive to previous years prescribed fire and wildfire. In past research the use of burned areas by deer increases dramatically during the following years (Klinger et al. 1989). Therefore, this model tests for these effects by using a lag on the fire variables. Preliminary analysis suggested a one year lag was sufficient as a model with a two year lag had a lower adjusted R square and the two year lag fire variables had t-statistics of .78 or lower (results available from the senior author). A variable for deer population in a given year is not included in the model due to lack of annual data on this variable (i. e., California Department of Fish and Game only occasionally collects data on deer populations). Unfortunately omission of current and previous years deer population may result in specification error, so the reader should keep this in mind. Future research should attempt to locate sites where population data is collected annually. We are not aware of any on National Forests in California, although there may be some in Oregon on special experimental forests.

The San Jacinto Ranger District Time Series Production Function Model is:

$$SJRD\ Deer\ harvest\ in\ year_{t} = f(RXFire_t, Wildfire_t, RXFire_{t-1}, Wildfire_{t-1}\ Total\_Precip_t, Oct\_Temp_t, Hunters_t, Hunters_{t-1}) \quad (1)$$

Where:

$RXfire_t$ and $RXfire_{t-1}$ = the acres of prescribed fire in year t and t–1, respectively.

$Wildfire_t$ and $Wildfire_{t-1}$ = the acres of wildfire in year t and t–1, respectively.

$Total\_Precip_t$ = the sum of precipitation for year t

Oct_Temp_t = temperature in October during the hunting season

$Hunters_t$ and $Hunters_{t-1}$ = number of hunters in year t and t–1, respectively.

Equation (1) is estimated using the log-log form for all variables but October temperature:

$$\ln(SJRD\ Deer\ harvest\ in\ year_t) = B_0 + B_1\ln(RXFire_t) + B_2\ln(Wildfire_t) + B_3\ln(RXFire_{t-1}) + B_4\ln(Wildfire_{t-1}) + B_5\ln(Total\_Precip_t) + B_6(Oct\_Temp_t) + B_7\ln(Hunters_t) + B_8\ln(Hunters_{t-1}) \quad (2)$$

This format allows for a non-linear relationship between the dependent variable and the independent variables. The double log form is a commonly used functional form for production functions, also known as Cobb-Douglas. This functional form allows for diminishing marginal effect of additional units of input (here, acres burned) on deer harvest if the coefficient on fire is less than one. With this functional form the coefficients for fire can be interpreted as elasticities. This is the percent change in deer harvest with a 1 % change in acres burned.

Details of study area

The San Jacinto Ranger District is located in southern California's San Bernardino National Forest near Palm Springs. As noted by the USDA Forest Service, "Some of the best deer hunting in Riverside County is found in this area." (Gibbs et al. 1995: 6). The San Jacinto Ranger District is an ideal area to estimate a production function between prescribed burning and deer harvest because prescribed fire has been used for more than 20 years to stem the long-term decline in deer populations since the 1970's (Paulek 1989, Gibbs, et al. 1995). Previous research on prescribed burning shows that fire enhances deer habitat and populations (California Department of Fish and Game-CDFG, 1998) but the economic benefits have not been quantified. The results of our analysis should be of some policy relevance as the San Jacinto Ranger District plans to increase the amount of prescribed burning by 50 to 100 % over the next few years (Walker 2001, Gibbs et al. 1995).

Within the San Jacinto Ranger District, the land is primarily managed by the USDA Forest Service, with small amounts of land administered by the State of California as the Mount San Jacinto State Park. The dominant vegetation within the San Jacinto Ranger District below 5,000 feet is chaparral. Annual rainfall for the chaparral biome is approximately 15 to 16 inches. Areas above 5,000 feet tend to be dominated by hardwoods and conifers such as live oak and Douglas fir with annual rainfall reaching up to 30 inches.

The land within the San Jacinto Ranger District is an area that evolved with fire as a natural environmental factor. Declining abundance of successional vegetation communities is considered to have the greatest long-term effects on deer populations (California Department of Fish and Game 1998). Historically, fire, either prescribed or wild, has been the primary mechanism for establishing these vegetation communities. Studies in California have noted that after a burn, increased deer numbers can be attributed to individuals moving into the area to feed (Klinger et al. 1989). Further, prescribed fire is thought to improve reproduction due to increased forage quality and an increase in fawn survival rates. The California Department of Fish and Game has noted a significant increase in buck harvest from 1987 to 1996 in hunt zones that had large fires, versus hunt zones that did not have large fires (California Department of Fish and Game 1998). To improve deer habitat in California, controlled burning has been underway in all the major parks and forests for many years (Kie 1984). Controlled burning to remove brush has been part of a program to create desirable deer habitat to mitigate the loss of deer habitat resulting from commercial and residential development.

Estimated production function

In Table 1, the coefficient for the initial effect of prescribed fire is significant at the .02 probability level, while the influence of prescribed fire in the previous year is less significant (t = 1.93) and its coefficient is about one-half the initial effect of prescribed burning. The sign on both of these variables are positive and the coefficients can be interpreted as an elasticity since we are using the log-log form.

Table 1. Time Series San Jacinto Ranger District log-log model.

Dependent Variable:
ln SJRD Deer Harvest

Variable	Coefficient	Std. Error	t-Statistic	Means[1]
Constant	2.4067	2.456	0.9799	1
ln_RXFire Acres *t*	0.2990	0.044	6.722	5.44
ln_RXFire Acres *t*–1	0.1475	0.076	1.933	5.46
ln_Wildfire Acres *t*	0.0909	0.059	1.541	7.32
ln_Wildfire Acres *t*–1	–0.3720	0.111	–3.352	7.39
ln_ Hunters *t*	1.157	0.669	1.729	7.81
ln_Hunters *t*–1	–1.815	0.499	–3.633	7.93
Oct_Temp	0.0919	0.050	1.834	70.17
AR(1)	0.1374	0.142	–0.964	N/A
Mean dependent var	3.967	S. E. of regression		0.218
Adj R-squared	0.945	F-statistic		22.85
Durbin-Watson	2.46	Prob (F-statistic)		0.042

[1] If the variable is in logs, the mean is given in logs.

Therefore, a one percent increase in acres prescribed burned will lead to a 0.3 % increase in deer harvest in the year of the burn and an additional 0.15 % in the following year. Wildfire acres burned has a slight positive effect on deer harvest the year of the fire, but is not significant since the probability level is .26. However the year following the wildfire, there is a larger negative effect that significant at the .078 probability level. The more hunters there are in year t has a positive effect on deer harvest in that year, although the effect is not significant at conventional levels as the probability level is .2 for our limited degrees of freedom. The prior years number of hunters has a somewhat larger and more significant negative effect on next years harvest of deer as the probability level is .068. October temperature has a small positive effect on deer harvest. The model's explanatory power is quite good with about 90 % of the variation in deer harvest in any given year explained by these variables. After correcting for first order autocorelation using the AR(1) term, the Durbin-Watson statistic of 2.46 suggests that autocorrelation is not a problem.

Applying the production function

To calculate the incremental effects of different levels of prescribed burning on deer harvest, the acres of prescribed burning is increased from one level to a higher level in the regression model, holding other variables at their mean. Specifically, the acres of prescribed fire variable in Table 1 is increased from the past aver-

Table 2. Regression model estimate of deer harvest response to prescribed burning.

RX acres burned	Additional RX acres burned	Assuming No Reduction in Wildfire		Assuming Corresponding Reduction in Wildfire	
		# Deer Harvested	Marginal Increase in Deer Harvest	# Deer Harvested	Marginal Increase in Deer Harvest
800	0	63	0	63	0
1800	1000	90	27	95	32
2800	1000	110	20	123	28

age of 800 acres to 1,800 acres and then to 2,800 acres and the predicted level of deer harvest is calculated at the mean of the other variables.

The results in Table 2 indicate additional deer harvest of 27 more deer with the first additional 1,000 acres burned (for a Ranger District total of 1,800 acres), holding constant the current amount of wildfire acres. Diminishing marginal effect is evident as prescribed burning a second 1,000 acres results in only 20 more deer harvested (for a total of 47 *more* deer with an *additional* 2,000 acres of burning). Table 2 also displays the results of a scenario whereby the additional prescribed burning acres results in a corresponding reduction in wildfire acres that burn each year. The premise of this scenario is that prescribed burning will reduce the underbrush and pine needles, and therefore reduce the fuel available on the ground. Thus with successful prescribed burning, there is insufficient fuel for a wildfire to develop. In this case the first 1,000 acre of prescribed burning with corresponding reduction in wildfire acres results in 32 more deer harvested rather than 27.

In order to determine the economic efficiency of additional prescribed burning it is necessary to compare the benefits of additional prescribed burning in the form of the economic value of deer harvest against the costs. The next section presents the development of the valuation data.

Valuation of deer hunting

According to California Department of Fish and Game, deer hunting is considered one of the major outdoor recreation activities in San Jacinto Ranger District. Previous research on deer hunting in California showed that increased success rates and opportunities to harvest a trophy deer increase the economic value of deer hunting (Loomis et al. 1989, Creel and Loomis 1992). The deer hunting season in the San Jacinto Ranger District is about one month long, correspondingly closely to the month of October each year. Generally, there have been sufficient deer tags offered to accommodate the number of hunters wishing to hunt in this area, so a lottery is not used to allocate tags. As is typical in most of California, there is a bag limit of one deer per hunter.

Contingent valuation of deer hunting quality

To calculate the incremental or marginal value of harvesting an additional deer, the contingent valuation method (CVM) was used. CVM involves asking the respondent how much more he or she would pay to increase the chances of harvesting a deer. We employed a simple open-ended question format where the respondent wrote down their maximum additional amount they would pay per trip. The format of payment (i. e., payment vehicle) was an increase in their trip costs. This was chosen as a more neutral means for the respondent to pay than increased hunting license fee, which sometimes engenders a "protest zero willingness to pay" against the fish and game management agency and its policies. Since the respondent does not actually pay the amount they write down, there is a concern regarding the accuracy of reported valuations. However, the bulk of the existing literature for recreation activities such as hunting shows a close correspondence between CVM estimates of net willingness to pay and estimates based on actual behavior such as the travel cost method (see Carson, et al. 1996). We believe the Carson, et al. results apply here as deer hunting is a recreation activity in which most hunters have repeated experience trading money in the form of travel costs for a recreational deer hunting experience. Therefore the concerns regarding hypothetical bias due to unfamiliarity with the good being valued is reduced considerably. CVM is also a valuation technique recommended by the U. S. Water Resources Council (1983) for use by federal agencies such as the U. S. Army Corps of Engineers and Bureau of Reclamation in performing benefit-cost analyses.

To obtain an estimate of net willingness to pay over and above current trip costs, hunters were first asked to record their trip expenditures. Then they were asked if the trip was worth more than this cost, and if so, they were asked "What is the maximum increase in your trip costs you would have paid for each trip to hunt this specific area?". Hunters that indicated the trip was not worth more than they spent were assigned a zero *net* willingness to pay for the current trip conditions.

In order to estimate how the value of this trip would change with increased chances of harvesting a deer, we asked the following question: "What if the hunting success in this area could be increased to the point where you would be almost certain to harvest a deer in this hunt zone each season. What is the maximum increase you would pay per trip to hunt this specific area if you knew you would be virtually certain to harvest a deer this season?". The difference between the answer to this question and the WTP for the current trip, is the incremental WTP to harvest a deer.

Hunter survey data

For cost effectiveness in data collection, a mail questionnaire was sent to a random sample of deer hunters with licenses for zone D19, which includes the San Jacinto Ranger District. Of 762 questionnaires mailed to deer hunters in California during the 1999 hunting season, 7 were undeliverable. A total of 356 deer hunters' responses were collected after two mailings. The response rate is approximately 47 %. Among these respondents, 69 did not hunt deer in San Jacinto Ranger District portion of zone D19. The response rate of this study is suspected to be low because many of the other hunters that did not hunt in the San Jacinto Ranger District portion of the D19 Hunt Zone may have failed to return the survey.

Valuation results

Willingness to pay results are summarized in Table 3. The net willingness to pay per trip for the current hunting quality conditions is $ 17.58. This relatively low value reflects the low average hunter success rate during that fall season. Net willingness to pay for a trip in which there was a 100 % certainty of harvesting a deer yields a value of $ 116.18. The *difference* between the improved hunting benefits and current hunting is $ 98.60. This difference reflects the marginal net willingness to pay to harvest a deer is $ 98.60 with a 90 % confidence interval of $ 120.45 to $ 76.75. That is, a hunter would pay nearly a $ 100 more for a trip in which he or she harvested a deer. Since the harvest bag limit is one deer, the incremental value of an additional deer harvest is $ 98.60. The confidence intervals are calculated as 1.64 standard errors above and below the mean.

Benefits of prescribed burning

Table 4 provides this study's bottom line – the annual deer hunting benefits of additional acres of prescribed burning. The initial deer hunting benefit response to

Table 3. Net willingness to pay to harvest a deer.

	Net WTP per Trip with Certain Deer Harvest	Net WTP per Trip with Current Hunting Success	Marginal Net WTP to Harvest a Deer
Mean	$ 116.18	$ 17.58	$ 98.60
Std. Error	$ 13.80	$ 4.04	$ 13.24
Upper 90 % CI	$ 138.95	$ 24.26	$ 120.45
Lower 90 % CI	$ 93.41	$ 10.91	$ 76.75

Table 4. Annual deer hunting benefits from increased prescribed burning.

RX acres burned	Additional RX acres burned	Assuming No Reduction in Wildfire		Assuming Corresponding Reduction in Wildfire	
		Deer Hunting Benefits	Marginal Benefits	Deer Hunting Benefits	Marginal Benefits
800	0	$ 6,173	0	$ 6,173	0
1800	1000	$ 8,847	$ 2,674	$ 9,301	$ 3,218
2800	1000	$ 10,767	$ 1,920	$ 12,031	$ 2,730

prescribed burning of an additional 1,000 acres ranges from $ 2,674 to $ 3,128 depending on whether prescribed burning does not or does equivalently reduce acres burned by wildfire. Prescribed burning an additional 1,000 acres for a San Jacinto Ranger District total of 2,800 acres results in deer hunting benefits calculated to be in the range from $ 1,920 to $ 2,730 each year, again depending on whether prescribed burning results in a equivalent reduction in wildfire acres or not.

Comparision to costs of prescribed burning

The costs of prescribed burning on the San Bernardino National Forest range from $ 210 to $ 240 per acre (Walker 2001). This is a lower total cost per acre than reported by González-Cabán and McKetta (1986), but substantially higher than the direct costs per acre for southwestern National Forests in Wood (1988). Nonetheless, if we use the $ 210 per acre figure, the full incremental costs of burning a 1,000 acres would be $ 210,000. The deer hunting benefits represent at most about 1.5 % of the total costs of the first 1,000 acres of prescribed burning. This finding can be used in two ways. First, the incremental costs of including deer objectives in the prescribed burn should not exceed $ 3 per acre, as the incremental deer hunting benefits are no larger than this. Second, the other multiple use benefits such as watershed and recreation, as well as the hazard fuel reduction benefits to adjacent communities would need to make up the difference if the prescribed burning program is to pass a benefit-cost test.

Conclusions

This study evaluated the response of deer harvest and deer hunting benefits to prescribed burning in the San Jacinto Ranger District in Southern California. To estimate hunter's benefits or willingness to pay (WTP) for harvesting an additional deer the Contingent Valuation Method was used, resulting in a mean WTP to harvest another deer of $ 98. The time-series regression model estimated a larger response to burning of the first 1,000 acres than the second 1,000 acres, although the deer harvest response did not fall off rapidly.

Using the marginal willingness to pay for harvesting another deer calculated from the CVM and the deer harvest response to prescribed fire, yields annual economic benefits ranging from $ 2,674 to $ 3,128 for an additional 1,000 acres prescribed burned or $ 2.67 to $ 3.13 per acre. The costs of prescribed burning on the San Bernardino National Forest range from $ 210 to $ 240 per acre. Thus the cost to burn an additional 1,000 acres is $ 210,000, which is an order of magnitude larger than the deer hunting benefits gained. Specifically, the deer hunting benefits of the first 1,000 acres represents about 1.5 % of the total costs. Thus, the other multiple use benefits of prescribed burning such as providing opportunities for dispersed recreation, protecting watershed as well as hazard fuel reduction to surrounding communities, would have to cover the rest. Investigating the extent of these benefits would be a logical next step in evaluating the economic efficiency of prescribed burning in the San Jacinto Ranger District.

This paper also demonstrated a time series production function approach to estimate the response of big game wildlife harvest to prescribed burning and wildfire. This approach uses commonly available time series data typically collected by wildlife management agencies. Thus the technique should have widespread applicability for evaluating prescribed burning programs aimed at improving big game habitat.

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