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FACTORS AFFECTING ANNUAL DEER HARVEST IN ARKANSAS

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ABSTRACT

An understanding of general forces affecting annual harvest is essential to the management of white-tailed deer *(Odocoileus virginianus)*. A predictive model based on such factors would be valuable to managers. The relationship between 27 different variables and annual, legal deer harvest in Arkansas was evaluated for 1957-1986. Variables most affecting harvest were soybean acreage, hay acreage, number of days in the deer season, rain during the deer season, and total state timber production, total state pulpwood production, and deer harvest 2 years prior. Because significant autocorrelation and heteroscedasticity were present in the variables, log-linear, first differencing and non-linear quasi-Newton regression methods were used in addition to ordinary least squares. First differencing removed autocorrelation and heteroscedasticity, but fit was not acceptable ($R^2 = 0.710$). Non-linear estimation of first differenced log transformed variables provided an acceptably high R^2 (0.896) with high significance of the individual parameter estimators. Factors associated with habitat quality 2 years prior most affected present-year deer harvest.

INTRODUCTION

Numerous attempts have been made to identify those factors most closely associated with white-tailed deer *(Odocoileus virginianus)* harvest (Fobes, 1945; Mechler, 1970; Hansen *et al.*, 1986). The ability to project harvest would enable managers to make better decisions regarding season parameters, and harvest and user regulations. Policy developed from incorrectly formulated models, however, can lead to disastrous consequences. Estimating legal deer harvest for policy reasons, thus, requires a proper knowledge and appreciation of the factors that influence annual harvest and the appropriate statistical tools to interpret them.

Many of the factors potentially affecting annual deer harvest, such as annual license sales, are classified as time-series variables. Present levels of time-series variables are at least partially dependent on antecedent levels. When this type of variable is used with ordinary least squares regression (OLS) modeling techniques, the error term may display autocorrelation and/or heteroscedasticity. Autocorrelation exists when the error term in one period is not independent of its value in other periods. Heteroscedasticity exists if there is unequal variance over time. The presence of either of these problems violates the fundamental assumptions of OLS regression (Neter and Wasserman, 1974). In addition, OLS methodology requires that the analyst specify the functional form of the estimated equation. There are, of course, no biological guidelines for specifying the relationships among variables potentially affecting deer harvest.

Two errors commonly derive from improper methodology in developing statistical models. First, variables are often included solely from their ability to reduce the unexplained variance of the dependent variable (Lovell, 1983). A second error is caused when the assumptions of OLS regression are not satisfied. This results in the estimates of the parameters not being best linear unbiased estimates of their true values. Therefore, the models themselves and structural inferences drawn from them may not be valid.

The objectives of this study were to (1) evaluate methods of modeling annual deer harvest using data commonly available to state wildlife agencies, and (2) use the most appropriate modeling technique to determine what factors affect annual deer harvest in Arkansas.

METHODS

Twenty-seven variables for the period of 1957 through 1983 were examined for inclusion in a reliable structural model of annual, legal deer harvest. Data were obtained from the Arkansas Game and Fish Commission, the Arkansas Cooperative Extension Service's Crop Reporting Service, the National Oceanographic and Atmospheric Administration, and the Arkansas Forestry Commission. For each year, variables examined were annual legal deer harvest, sales of resident hunting licenses and dog licenses, number of days in the modern weapon, archery, crossbow and muzzleloader seasons, number of seasons per year for modern weapons, bag limits, total state production of timber and pulpwood, acreages of corn, soybeans, oats, hay, sorghum, wheat and rice, number of farms, and November rainfall in the Coastal Plain region (where most of the state's deer harvest is taken). Each time-series variable was also lagged 1 and 2 years.

Variables that were used in the modeling effort were chosen by a three step process. First, variables that showed a high correlation ($r > 0.75$) with the dependent variable were noted. Second, for these variables, only if there was a strong visual relationship between the dependent and independent variables, was the variable designated for possible inclusion in the modeling effort. Final selection of variables for inclusion was made with the stepwise regression process. A parameter significance of $P < 0.1$ was required for final inclusion in the model (Wilkinson, 1986). First-differencing (Neter and Wasserman, 1974) and logarithmic transformations were performed on all variables.

Five separate models were analyzed and the residuals checked for compliance with the underlying assumptions of OLS regression (Steel and Torrie, 1960). The five models were 1) standard OLS regression, 2) OLS regression of first-differenced data, 3) OLS regression of log-linear transformed data, 4) non-linear quasi-Newton regression (Wilkinson, 1986) of untransformed variables and 5) log-linear estimation of first-differenced and log-transformed data using quasi-Newton regression techniques (Wilkinson, 1986). All analyses were performed using SYSTAT (Wilkinson, 1986). Statistical significance was accepted at the $P < 0.05$ probability level.

Elasticities (Pindyck and Rubinfeld, 1981) were computed for each variable included in the models. Elasticity is a ratio of responsiveness and is computed by dividing the percent change in the dependent variable by the associated percentage change in an independent variable. An elasticity value of 2.0 would indicate that for every 1% change in the independent variable a 2% change would occur in the dependent variable. If an elasticity value is less than one, the relationship is said to be inelastic. A value of one is said to be unitary elasticity, and a value greater than one is termed elastic.

RESULTS AND DISCUSSION

Variables chosen were soybean acreage (current-year and 2 years prior), current-year hay acreage, state total timber production (2 years prior), state pulpwood production (2 years prior), deer harvest (2 years prior), days in modern weapon seasons and rain during the month of November (Table 1).

The error terms associated with three of the models resulted in violations of OLS regression assumptions. OLS regression on untransformed variables produced a model with a high R^2 (0.93) but autocorrelation and heteroscedasticity were present. OLS regression of first-differenced variables produced a model free of autocorrelation and heteroscedasticy but with a relatively low R^2 value (0.71). The log-linear OLS regression (R^2 = 0.93) model resulted in heteroscedasticy in the residuals.

The error terms for two models (conformed to the assumptions of OLS regression. The non-linear estimation process using untransformed data, free of the assumptions shackling OLS regression, provided the best fit (R^2 = 0.994) and high "t" values of the parameter estimators. Further, non-linear regression provided a multidimensional response surface conceptually compatible with a dynamic process such as wildlife harvest over time. However, untransformed data used in this method was not free of time-related bias. Sequential observations of independent variables had a high multiple correlation coefficient but could have been related to a third unidentified variable proxied by time. Without addressing this problem, increasingly distorted projections would occur.

The R^2 (0.896) for the differenced, log-transformed variable set modeled with the quasi-Newton method was lower than for the non-linear estimation of untransformed variables. However, the transformed data set had several advantages. First, since the variables were stripped of long-term time trends before modeling, their true relationship to each other was modeled. Second, auto-or serial correlation was removed from the series before modeling. Even though lagged variables were present, their selection for the model was not based on their ability to reduce autocorrelation. Rather, each variable stood alone in explaining variation of the dependent term. Finally, the quasi-Newton method of regression converges on the parameter estimates through an iterative process which can continue to the degree of precision desired. Therefore, parameter estimates generally had a lower standard error associated with them than with other methods. Only one variable was not significant at the 0.05 level, and only two were not significant at the 0.01 level (Table 1).

We hypothesize that the independent variables included in the models may be grouped as 2 sets of factors: those affecting hunt intensity and those influencing deer population density. Variables that could affect population density were timber production, pulpwood production, soybean acreage and deer harvest (all two years prior). Factors possibly related to hunt intensity were those for the current year: soybean acreage, hay acreage, days in modern weapon seasons and rainfall during November.

With the exception of current-year soybean acreage, all factors were found to be inelastic. That is, current-year deer harvest was not very responsive to changes in the independent variables (Table 1). Factors associated with population density two years prior had a stronger (2 to 3 times) influence on deer harvest than factors associated with hunt intensity but were only slightly inelastic with respect to harvest.

There are many possible explanations for how each variable related to population density could affect annual deer harvest. Timber production data used in this study includes clear cutting, which connotes severe stand disturbances and site preparation practices. These activities may disrupt forage production and diminish cover for a period of 1 to 2 years. In contrast, pulpwood production includes operations that often remove mid-story and create canopy openings without site preparation, thereby providing increased browse production. Thus, the difference in signs between pulpwood production and total timber production may reflect differences in animal use of harvested areas or alternatively, the ability of hunters to harvest deer. Soybean production two years prior could have provided forage during late spring and

Table 1. Results of log-linear estimation of annual deer harvest in Arkansas from 1956-1986 using Quasi-Newton non-linear regression with first-differenced and logged data.

Variables	Units	Elasticity	Coefficients	T-value
Constant			-0.311	-2.549***
Present-year				
Soybean acreage	Hectares x 1000000	-1.21	-1.209	-3.489***
Hay acreage	Hectares x 1000000	+0.31	0.307	1.412*
Seasons length, modern weapons	Days	+0.35	0.354	2.058**
November rainfall	Cm.	+0.15	0.150	3.125***
Lagged 2 years				
Soybean acreage	Hectares x 1000000	+0.74	0.740	3.045***
Timber production	$Meters^3$ x 1000	-0.85	-0.845	-2.118***
Pulp production	$Meters^3$ x 1000	+0.99	0.988	2.498***
Deer harvest	Animals	-0.46	-0.462	-3.787***

* $P < 0.10$.
** $P < 0.05$.
*** $P < 0.01$.

early summer, and beans prior to winter. Thus, a healthy herd two years previous would provide many of the animals that would be harvested in the current year.

The low elasticities for the variables we feel affected hunt intensity, such as modern weapon seaon length, suggest that these factors had minimal direct effect on deer harvest. The low responsiveness of deer harvest to season length is important to policy decisions. For example, our analysis shows that increasing the hunting season from 30 to 35 days (a 16.7% increase) would result in only a 5.8% increase in deer harvest. Thus, season length could be increased with the expectation that deer kill would not rise proportionately.

There are also numerous explanations for how variables related to hunt intensity could affect annual deer harvest. Of all the variables, current-year soybean acreage had the strongest statistical relationship to deer harvest. The negative elasticity of soybean acreage could be a result of soybeans typically being produced in large fields unsuitable for hunting. Conversely, hay fields in Arkansas are usually much smaller than soybean fields and often provide forage and cover during hunting season. Thus, hay acreage could positively affect harvest. Rainfall may reduce hunter numbers and deer harvest (Curtis 1972; Mechler 1970), but in this study total rainfall during the hunting season had a slightly positive effect on harvest.

CONCLUSIONS

Deer harvest can be projected using data commonly available to state wildlife agencies. However, for best results data must be stripped of their time-dependency before the modeling process. Quasi-Newton nonlinear regression, using first-differenced, logged data, was the most appropriate modeling procedure. Some variables, particularly those related to habitat or previous harvests, may affect deer harvest in subsequent time periods. Therefore, variables should be examined prior to modeling for significant time lags, and so that autocorrelation can be removed.

Based on results of this study, factors associated with habitat quality two years prior to harvest were the most important for determining present-year deer harvest. Only one hunting season factor, days in modern weapon seasons, was important. Many other variables that could affect annual deer harvest, however, were not examined. For example, off-road vehicle use or sales, and sex-age ratios of earlier deer harvests could affect harvest, but these data were not available. It may also be important when modeling deer harvest to account for differences in variables among physiographic regions.

Definitive biological cause-and-effect relationships are more difficult to develop than a valid statistical model. While the modeling process we utilized insures statistical validity, adequate explanation of model structure is more difficult. One factor that makes interpreting the model results more difficult is that the data we used was aggregated at the state level. Accordingly, additional research on a regional level is required.

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