

RESPONSE OF AVERAGE DEER WEIGHT TO THE REINTRODUCTION OF BOBCATS
ON CUMBERLAND ISLAND, GEORGIA

Term Project

ISQS 5349

Fall 1994

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Good job!

See comments inside.

Project: 98
course: A

Post-it[™] telephone message pad 7660
BRAND

To Zack 378C
Date _____ Time _____

WHILE YOU WERE OUT

M THANKS - WISH TIME
of TEXT WAS WRITTEN
Phone No. IN PLAIN ENGLISH

TELEPHONED	PLEASE CALL
WAS IN TO SEE YOU	WILL CALL BACK
WANTS TO SEE YOU	URGENT
RETURNED YOUR CALL	

Message From Bob Warren.
Please copy if you wish
& return original to
me.

Operator Jenny

TABLE OF CONTENTS

ABSTRACT	1
INTRODUCTION	1
DATA	3
Source	3
Characteristics	3
Variable Descriptions and Limitations	3
Sample size	5
Adequacy of the variables	6
<i>A PRIORI</i> MODELLING	7
Assumption of a probabilistic process	7
Functional specification of the mean response	8
Constant Variance Assumption	9
Uncorrelated Errors Assumption	9
Normality Assumption	9
Signs of regression coefficients	9
DATA ANALYSIS	10
Overview	10
Full-rank models	10
Interaction terms	11
Inclusion of the quadratic age class term	12
Evaluating variables included in the model	12
Evaluating assumptions of the models	13
Final model	15
CONCLUSIONS	16
REFERENCES	17
APPENDICES	18

ABSTRACT

Bobcats were reintroduced to Cumberland Island National Seashore in 1988 and 1989. Since the reintroduction of bobcats, park managers have observed a decline in the percent of hunters which are successful in harvesting a deer during the annual hunts. I hypothesized that predation of white-tailed deer by bobcats is causing a decline in the density of white-tailed deer on the island, and I predicted that if such a decline is occurring, there should also be increases in the average weight of deer on the island. To test this hypothesis, I analyzed data collected during deer hunts before and after the bobcat reintroduction using covariance models. I used age class of harvested deer, gender of harvested deer, year of harvest, and presence of bobcats as the prediction variables. The eviscerated weight of harvest deer was the response variable. Because the effect of bobcats was nested with the year effect, year of harvest and bobcats were confounded. Results from the analysis supported the prediction that deer weights have increased since the reintroduction of bobcats, but did not separate the effect of bobcats from other possible year effects. A quadratic term included in the model for age class significantly improved the model. There was a significant interaction between gender and age class in their effect on deer weights.

INTRODUCTION

Cumberland Island is the largest and southernmost of Georgia's coastal barrier island, located just north of the Georgia-Florida border about 2 km east of the mainland. It is administered by the National Park Service as a National Seashore, accessible only by boat or plane. The island is 25 km long and 1-6 km wide. It contains a diverse flora and fauna, including white-tailed deer (Odocoileus virginianus). There have been no native mammalian predators on

the island other than man during this century.

During 1988 and 1989, the National Park Service and the University of Georgia released a total of 30 wild adult bobcats (*Felis rufus*) on Cumberland Island. One question associated with the release of the bobcats was the effect of the reintroduction on the white-tailed deer population. Prior to the reintroduction of bobcat on Cumberland, Warren et al. (1990) suggested that nutrition might be a primary factor in determining body weights of deer on Cumberland. Counts of abomasal parasites in deer rumens suggested that during 1986 to 1988, the deer herd on Cumberland was at or slightly in excess of the carrying capacity of the island, and deer on Cumberland Island were judged to be nutritionally stressed (Warren 1990). Hunter-success ratios for the period 1984 - 1993 have declined since the bobcat reintroduction was completed in 1990 (Fig. 1).

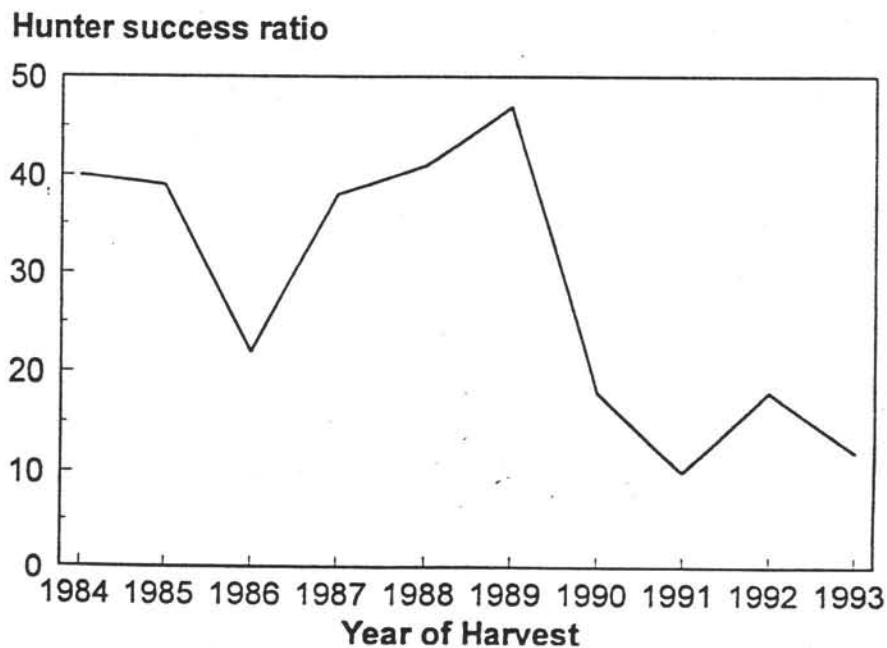


Figure 1. Percent of hunters successful each year vs. the year for deer hunts on Cumberland Island, GA, 1984-1993.



Although many factors may influence hunter-success ratios, including deer movement rates, skill of hunters, weather factors, and other factors which are not constant among time periods, long-term trends in hunter harvests may indicate trends in deer population size. My hypothesis is that bobcat predation has caused a decline in the white-tailed deer population size on Cumberland Island. Because a decline in the number of deer on the island should increase the amount of food available for remaining deer, I predict from this hypothesis that average deer weights on Cumberland Island have increased since the bobcat reintroduction was completed in 1990. I used regression analysis to estimate the effect of the bobcat reintroduction on average change per year in deer weights, holding the effects of year, age class of the deer, and gender of the deer constant.

DATA

Source.--The eviscerated or total weight, gender, and jawbone of hunter-killed deer on Cumberland Island were collected at check stations on the island during 5 managed hunts each year between 1984 - 1992. The data were collected primarily by park rangers, assisted by University of Georgia researchers in some years. Although all deer killed during each hunt were brought to the check stations, jawbones were not collected from all deer. Deer without complete information were excluded from the analysis. I obtained access to this data through my master's thesis work on the bobcat reintroduction.

Characteristics.--This data set represents a combination of time series and cross-sectional data. During a consecutive series of 9 years the number of deer killed per year ranged from 33 to 207. The data are observational in nature, indicating a random-x model is appropriate.

Variable Descriptions and Limitations.--The prediction variables measured for this analysis are age class of harvested deer, gender of harvested deer, year of harvest, and presence of

bobcats. The response variable is the eviscerated weight of deer, measured in pounds.

Age class of harvested deer was estimated after hunts were completed from tooth eruption and wear on collected jawbones (Severinghaus 1949). Unfortunately, there is some uncertainty in estimation of age from tooth wear, indicating there probably is some measurement error associated with this variable. Through the age class of 1.5 years, white-tailed deer can be aged accurately by tooth eruptions. At the ages of 2.5 years and beyond, the deer must be aged by tooth wear, which is less accurate.

Using a prediction variable which contains a component of measurement error results in biased estimates of model parameters (Neter et al. 1989, P. Westfall, pers. comm.). Initially, deer were assigned to 6 age classes: 0.5, 1.5, 2.5, 3.5, 4.5, and 5.5+ years old. However, an analysis of variance followed by a Bonferroni test for significant differences found no significant differences between weights of 4.5 year-old deer and 5.5 year-old deer at the $\alpha = 0.05$ level (Appendix 1). Because the data set indicated no significant differences in weights, I combined the 2 older age classes to reduce measurement error associated with aging older deer. Undoubtedly there is some measurement error associated with the other estimates of deer age. However, for the purposes of this analysis I chose to assume that bias introduced by these errors did not significantly affect my conclusions. I considered age class to be an ordered categorical variable.

Gender of each harvested deer was recorded as male or female by the check station personnel. Gender is easy to determine, therefore I assumed that gender was recorded without measurement error. Gender was an unordered categorical variable.

Hunts occurred in November - January of each fall and winter. Deer were assigned to a year of harvest based on when the winter in which they were killed began. For example, deer

killed during the winter of 1984-1985 were assigned to the year 1984. Year of harvest could be considered an ordered categorical variable, especially in that conditions a year previously may positively or negatively influence conditions in a current year. However, again I did not expect the relationship between year of harvest and weight to be linear. Therefore I modeled year of harvest as an unordered categorical variable.

For purposes of this analysis, bobcats are considered "present" in the years after the reintroduction was completed, i.e. 1990 - 1992. I chose 1990 as the first year bobcats would have an effect because only 12 bobcats were present between 1988 - 1989. The additional 18 bobcats were not put on the island until the fall of 1989, when the 1989 deer were already being harvested. Therefore 1990 is the first year in which the full impact of bobcat predation might be reflected by changes in deer weights. The presence of bobcats was nested within the year of harvest variable, bobcats being absent in 1984-1989 and present in 1990-1992. Therefore it also was modeled as an unordered categorical variable.

Eviscerated weight of deer, the response variable, was measured in pounds. Over the total range of weights considered, 18 to 100 pounds, eviscerated weight was a reasonable approximation of a continuous variable. In 1984, and in isolated cases in other years, total weight rather than eviscerated weight was recorded. Total weight was converted to an estimate of eviscerated weight by dividing total weight by 1.35 (Anonymous 1984). This introduces measurement error into the measurement of deer weight. However, measurement error in the response variable does not violate any assumptions of regression analysis (Neter et al. 1989).

Sample size.--I analyzed data collected 688 deer harvested between 1984 and 1992. The number of deer in each category of gender, age class, and year are shown in Table 1.

Table 1. Number of hunter-killed deer sampled in each age class, gender, and year of harvest category on Cumberland Island, Georgia, 1984-1992.

Year	0.5 years		1.5 years		2.5 years		3.5 years		4.5+ years	
	M	F	M	F	M	F	M	F	M	F
1984	1	0	10	9	2	6	5	1	13	18
1985	8	5	3	7	9	5	8	6	15	23
1986	3	2	8	5	4	6	8	3	14	22
1987	12	10	5	1	6	2	4	2	9	18
1988	3	18	36	16	5	8	12	10	25	20
1989	5	2	8	7	14	19	4	8	9	26
1990	3	1	6	0	6	6	9	4	17	15
1991	4	3	3	0	5	5	4	1	7	6
1992	4	3	3	3	4	5	3	3	2	4

bobcats {

Three-hundred forty-four males and 344 females were included in the analysis. The number of deer in each age class was: 87 0.5 year-old deer, 130 1.5 year-old deer, 117 2.5 year-old deer, 95 3.5 year-old deer, and 259 4.5+ year-old deer. The number of deer included from each year was: 65 in 1984, 89 in 1985, 75 in 1986, 69 in 1987, 153 in 1988, 102 in 1989, 67 in 1990, 34 in 1991, and 34 in 1992. The number of individuals in each combination of gender, year, and age class was highly variable, and there were 3 cells with no observations. Five hundred and fifty-three deer were collected prior to 1990 (bobcats absent), and 135 deer were collected from 1990-1992 (bobcats present).

Adequacy of the variables.--Factors influencing size of white-tailed deer include geographic region, nutritional status, season of the year, age, gender, and genetic potential (Sauer 1984, Warren et al. 1990). I assume the variables of geographic region and genetic potential are similar for all deer in the Cumberland Island population. Season is constant among all of the

collection periods, and age and gender have been measured. Nutritional status is the least adequately represented variable in the study. Nutritional status of white-tailed deer is a function of food production for the year, the number of animals competing for the food, and variations among individuals in their ability to compete for food. The variable year should account for some of the variation in nutritional status caused by changes in food production and deer density among years. However a limitation of this study is that there is no direct measure of food availability. Because presence of bobcats is thought to act on deer weights through changes in deer density, and since deer density and food availability both influence the year effect, year and presence of bobcats are confounded in the model.

A PRIORI MODELLING

Assumption of a probabilistic process.--A basic underlying assumption of regression analysis is that the process which produces the response variable is sufficiently similar to a random process that we can make valid inferences concerning the mean and variance of the probability distribution of the response variable. The process hunters use in selecting deer to harvest casts doubt on the validity of this assumption in this situation. Hunters are thought to be more likely to select male deer than female deer, and more likely to select large "trophy" males than smaller males, females, and fawns.

Fortunately, the characteristics of the deer herd on Cumberland make these types of violation less likely than in other harvest situations, although they probably still occur. The Cumberland Island deer, being chronically nutritionally stressed (at least prior to the bobcat reintroduction), are smaller than deer on the mainland, and are rarely "trophy" animals (Warren 1990). Hunters are therefore more likely to harvest adults at random from the population. Fawns

(0.5 year-old-deer) probably are still less likely to be harvested than older deer. Although these violations occur, if I assume that the form of these violations remains constant among years, I can still draw conclusions about the relative effects of prediction variables in changing average deer weights. *weight is selected at random (o.k.)*

Functional specification of the mean response.--Using the general rule of thumb that the number of parameters in a model should not exceed the square root of the sample size, the number of parameters in the model should not exceed 26, and preferably will be fewer. The most general model of the effect of predictor variables on average weights of harvested deer that I considered was: $WTCLASS = \beta_0 + \beta_1 MALE + \beta_2 AGECLASS + \beta_3 AGECLASS^2 + \beta_4 BOBCAT + \beta_5 1984 + \beta_6 1985 + \beta_7 1986 + \beta_8 1987 + \beta_9 1988 + \beta_{10} 1989 + \beta_{11} 1990 + \beta_{12} 1991 + \beta_{13} MALE * AGECLASS + \beta_{14} MALE * BOBCAT + \beta_{15} BOBCAT * AGECLASS + \epsilon$

As described under variable descriptions, to allow gender, year of harvest, and presence of bobcats to take on unspecified functional forms, each was treated as an unordered categorical variable. Age class was modelled as an ordered categorical variable. However, because I did not expect a linear relationship between age class and weight, I included a quadratic term for age class in the model. Presence of bobcats was not actually a main effect because it is a nested variable. However, by entering it into the model before I entered year variables I believed I would be able separate variation attributable to bobcats from variation attributable to year. The bobcat and year variables are confounded, and any conclusions about the effect of bobcats as opposed to the effect of year are tentative.

An age class*gender interaction effect on weight is reasonable, because male deer grow larger than females. A gender*bobcat interaction is reasonable because bobcat may preferentially

20 No ^{Confuse interaction with correlation} They are related concepts.
select smaller deer. A age class*bobcat interaction is reasonable for the same reason.

Interactions of year with gender and age, and a three-way interaction among gender, age, and year based on differing responses of males and females and young and old deer to changes in food availability were also reasonable. However the size of the data set did not support analysis of these variables in a regression model.

Constant Variance Assumption.--As happens with biological data, variance of deer weights may increase as the average weight increases with the age class of deer. I did not expect variance to change because of gender of deer, year, or presence of bobcats.

Uncorrelated Errors Assumption.--The nutritional status of deer in one year may affect the weight of deer in the next year, so there is a possibility that errors are correlated among years. However, because year is being modelled as an unordered categorical variable, each year will be considered separately in a regression equation, so a correlation of errors caused by effects of the previous year was not be a consideration in these individual models.

Normality Assumption.--I expected weights of deer to be normally distributed. ^{exactly?}

Signs of regression coefficients.--

- Coefficients associated with age class: I expected these coefficients to be positive because weight increases with the age of the deer.
- Coefficient associated with gender: Females weigh less than males, so I expected the coefficient for males to be positive.
- Coefficient associated with presence of bobcats: I hypothesized that the presence of bobcats leads to an increase in deer weights, so I also expected this coefficient to be positive.
- Coefficients associated with year: I expected both positive and negative coefficients, depending

on the year which is left out of the model.

- Interaction coefficients: Because I expected a gender classification of male and the presence of bobcats to have positive effects on weights, I expected the coefficients of these interactions to be positive.

DATA ANALYSIS

Overview.--The steps I went through in selecting variables and evaluating the models were: (1) evaluating the importance of interaction terms and selecting interactions to be included in the model; (2) testing the necessity for inclusion of a quadratic age class term in the model using a full/restricted F-test; (3) evaluating the importance of variables included in the model; (4) evaluating other assumptions of the selected model and considering transformations; and (5) selecting a final model. My objective was to start with the most general model and evaluate the inclusion of terms until a parsimonious model was selected. Testing for the inclusion of the squared age class term constituted a test of the assumption of linearity for the only ordered categorical variable in the model.

Full-rank models.--My first foray into model evaluation showed that the nested effect of the bobcat variable was a more serious complication than I had supposed. A regression model involving year and bobcat variables was not full rank unless I dropped two of the year dummy variables (one from the period when bobcats were present and one from the period when bobcats were absent) or the bobcat variable. My initial approach was to drop two of the dummy year variables. The selection criteria I used to determine which 2 years to combine was no significant difference between the years which were to be combined. Using a model without bobcat and without the 1990 year dummy variable, I tested whether any of the years prior to the bobcat

reintroduction were significantly different from 1990. The year 1986 was the only year prior to the reintroduction which was not significantly different from 1990 (Appendix 2), so I chose to drop the dummy variables for 1986 and 1990 in all further evaluation of models including the bobcat variable.

The selection of which years to drop affected whether or not the bobcat variable was significant in the model (Appendix 2). I also considered a model where I combined 1989 and 1990. In this model the bobcat variable was significant, whereas in the combined 1986 and 1990 model the bobcat variable was not significant. However I felt it was more appropriate to combine 1986 and 1990 than it was to combine 2 significantly different years.

Interaction terms.--Because interaction terms complicate interpretation of a model, I did not want to include interaction terms that did not contribute to the models. I compared 4 models to select interaction terms to be included: (1) the most general model, with all interactions and a squared age class variable, (2) a model with all interactions and no squared age class variable, (3) a model with only the gender*age class interaction and a squared age class variable, and (4) a model with only the gender*age class variable and no squared interaction term.

The gender*age class interaction was the only significant interaction in the first 2 models (Appendix 3). A comparison of the root MSE and adjusted R^2 for the 4 models is given in Table

2.

Table 2. Root MSE and adjusted R^2 for models with and without nonsignificant interaction terms and a quadratic term for age class.

Variables included	Root MSE	Adj. R^2
All interactions, age ² term	8.97	0.66
All interactions, no age ² term	9.49	0.62
Gender*age class, age ² term	8.97	0.66
Gender*age class, no age ² term	9.49	0.62

The inclusion of nonsignificant interaction terms did not improve the models, so the gender*bobcat and age class*bobcat interactions were not considered further.

Inclusion of the quadratic age class term--Table 2 demonstrates that inclusion of a quadratic term for age class did decrease root MSE of models and increase adjusted R^2 . To formally test for the significance of the quadratic term, I conducted a full/reduced model F-test, with the full model including the quadratic term and the reduced model excluding it. Values used in calculating the F-test can be found in Appendix 3.

H_0 : Reduced model is appropriate.

H_a : Full model is appropriate.

The calculated F-statistic was 835.74. The test statistic was $F_{1,675,0.05} = 3.84$. The calculated statistic was greater than the test statistic, so I rejected the null hypothesis. The quadratic term for age class was included in all further models.

Handwritten note: This is wrong. In this case, $t^2 = F$, or $(9.04)^2 = F$

Evaluating variables included in the model--In the full model, both gender and bobcat were insignificant variables (Appendix 3), although the gender*age class interaction was significant. Removing the gender variable from the model caused the root MSE to decrease to 8.96 from 8.97, and had no effect on the adjusted R^2 at 2 decimal places. I had expected gender to be a significant variable *a priori*. However, in the dummy variable structure, lack of

significance of the gender variable merely indicates that regression lines for males and females have the same intercept. The significant interaction of gender with age class indicates that the weights of males and females respond differently to increases in age. Since this pattern matches my subject matter expectations that weight differences between males and females are least when they are fawns and greatest when they are adults, I decided in the interests of parsimony it was appropriate to exclude gender as a variable in the model, while retaining the gender*age class interaction term.

The non-significance of the bobcat term was more disturbing. As discussed earlier, the significance of this term depended on which 2 years were combined and dropped from the model. Although the effect of bobcats was the primary focus of this analysis, I decided in light of the nested effect of bobcats within years, and the questionable practice of dropping 2 years which was necessary to analyze this effect, I would drop the bobcat variable from the model, and draw my conclusions about the effect of bobcats from information contained within the year dummy variables. While this makes my conclusions about bobcats less strongly supported, I believe it is appropriate considering the type of data collected. Because the bobcat variable was dropped, all appropriate dummy variables for year could be included in the parsimonious model.

Evaluating assumptions of the models.--I used partial regression plots (Appendix 5), a predicted vs. residual plot (Fig. 2), and a quantile-quantile plot (Fig. 3) to evaluate the assumptions of linearity, constant variance, and normality. The assumption of uncorrelated error was assumed to be satisfied by modelling each year separately in the regression. No gross violations of assumptions were found. Nonlinearity of the age class variable is expected, because of the significance of the quadratic term. There is a slight indication of increasing variance with

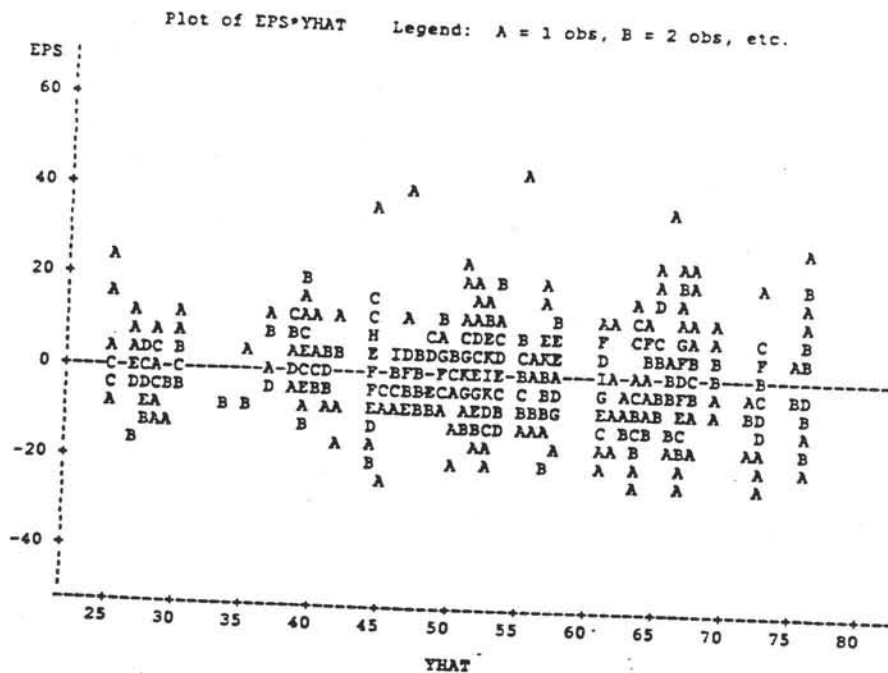


Figure 2. A plot of the predicted vs. the residual values using the final model.

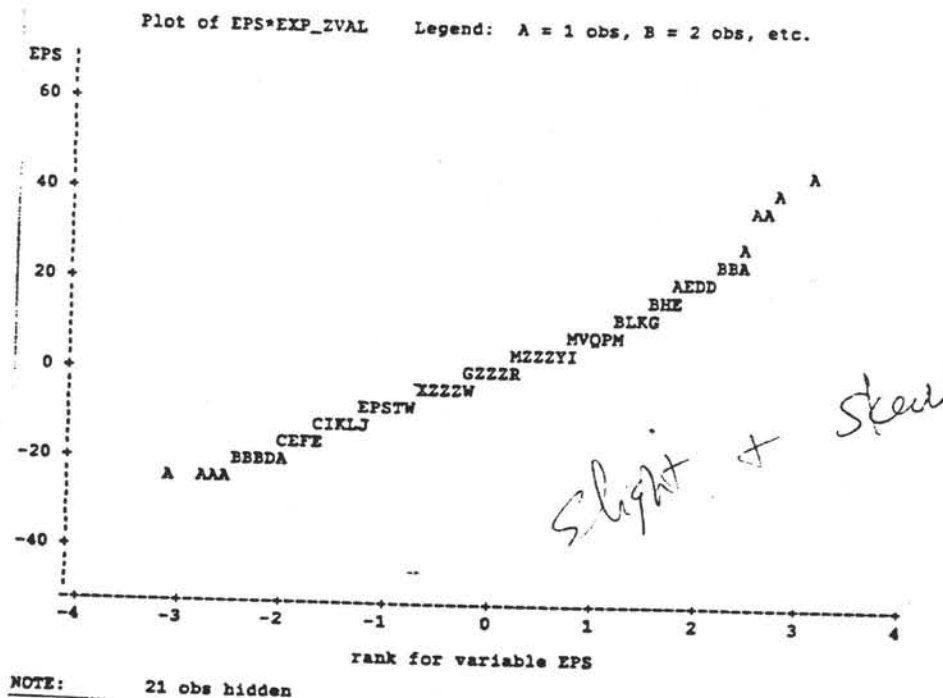


Figure 3. A normal quantile-quantile plot of the residuals using the final model.

increasing weight in the predicted vs. residual plot, and a slight indication of nonnormal variance in a wiggle at the upper end of the quantile-quantile plot. However, if we do not consider the 4 outliers which appear to be causing these violations, the plots indicate the assumptions appear to be satisfied. With such a large data set (688 observations), outliers are not likely to be very influential. Therefore I chose not to make any corrective measures.

Final model.--The final model chosen was: $WTCLASS = \beta_0 + \beta_1 AGECLASS + \beta_2 AGECLASS^2 + \beta_3 1984 + \beta_4 1985 + \beta_5 1986 + \beta_6 1987 + \beta_7 1988 + \beta_8 1989 + \beta_9 1990 + \beta_{10} 1991 + \beta_{11} MALE * AGECLASS + \epsilon$. The estimated parameters for each combination of year and gender are given in Table 3. A example of the interaction between gender and age class is given in Fig. 4.

Table 3. Estimated parameters of intercept, slope of age class, and slope of age class² from the final model predicting deer weights, using gender, age class, and year of harvest as predictors.

YEAR	INTERCEPT	AGECLASS		AGECLASS ²
		if male	if female	
1984	20.70	19.48	16.12	-2.00
1985	20.11	19.48	16.12	-2.00
1986	25.46	19.48	16.12	-2.00
1987	17.13	19.48	16.12	-2.00
1988	19.63	19.48	16.12	-2.00
1989	19.02	19.48	16.12	-2.00
1990	25.86	19.48	16.12	-2.00
1991	28.50	19.48	16.12	-2.00
1992	34.10	19.48	16.12	-2.00

Dressed weight of deer (lbs)

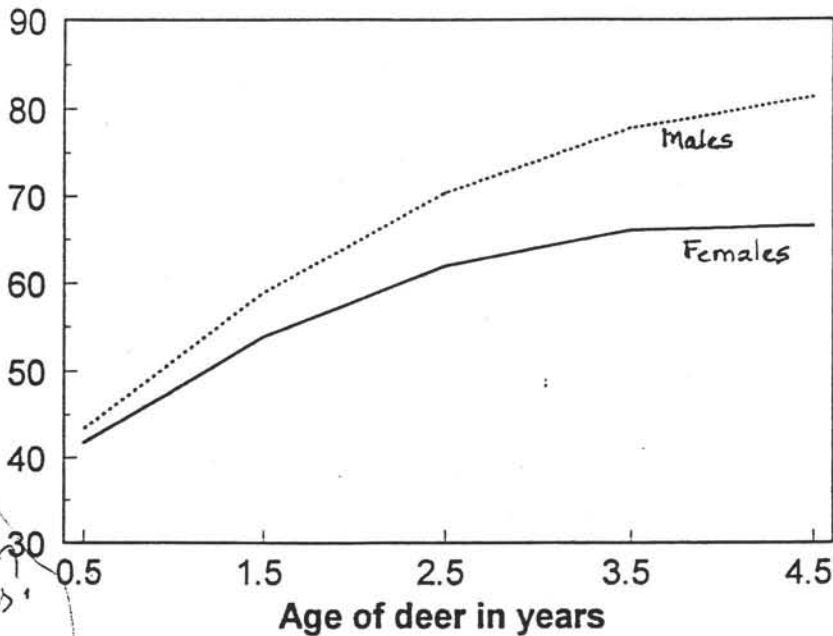


Figure 4. Interaction between age class and gender in estimate eviscerated weight of deer in 1992 using the final model.

CONCLUSIONS

The problems associated with trying the use this data set to test the prediction that deer weights increased after the reintroduction of bobcats were worse than initially suspected.

However the intercepts of the final model do provide a test of significant differences in weights among years, and I can compare years before and after the reintroduction of bobcats. Weights in 1992 were significantly greater than weights in any other year (Appendix 4, $\alpha = 0.05$).

Weights in 1990 and 1991 were not significantly different from each other or from weights in 1986, but were significantly greater than weights in the all other previous years (Appendix 2, $\alpha = 0.05$).

These results support the hypothesis that deer weights have increased since the reintroduction of bobcats. However these results can not separate the effects of bobcats from

other potential year effects, such as variations in food production. Therefore these results do not prove that bobcats were the cause of the increased weights.

If this research question is to be pursued further, my results suggest that stronger conclusions could be drawn if other factors currently included in the year effect, such as food production and deer density, were explicitly modeled. I would also hypothesize that the effects of bobcats will vary with bobcat density, so information on bobcat density would be useful in a new model.

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General Linear Models Procedure

Dependent Variable: WTCLASS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	112945.62605	3764.85420	48.89	0.0001
Error	657	50592.49178	77.00531		
Corrected Total	687	163538.11783			

R-Square	C.V.	Root MSE	WTCLASS Mean
0.690638	16.730200	8.7752672	52.45165805

Source	DF	Type I SS	Mean Square	F Value	Pr > F
AGECLASS	5	76322.4020	15264.4804	198.23	0.0001
YEAR	8	13552.8446	1694.1056	22.00	0.0001
BOBCAT	0	0.0000			
SEX	1	16740.9574	16740.9574	217.40	0.0001
AGECLASS*SEX	5	4496.2733	899.2547	11.68	0.0001
AGECLASS*BOBCAT	5	1072.6693	214.5339	2.79	0.0168
BOBCAT*SEX	1	582.7622	582.7622	7.57	0.0061
AGECLASS*BOBCAT*SEX	5	177.7172	35.5434	0.46	0.8049

Source	DF	Type III SS	Mean Square	F Value	Pr > F
AGECLASS	5	40326.85581	8065.37116	104.74	0.0001
YEAR	7	4495.74405	642.24915	8.34	0.0001
BOBCAT	0	0.00000			
SEX	1	9140.43298	9140.43298	118.70	0.0001
AGECLASS*SEX	5	2055.43601	411.08720	5.34	0.0001
AGECLASS*BOBCAT	5	1358.92160	271.78432	3.53	0.0037
BOBCAT*SEX	1	390.51672	390.51672	5.07	0.0247
AGECLASS*BOBCAT*SEX	5	177.71722	35.54344	0.46	0.8049

General Linear Models Procedure

Bonferroni (Dunn) T tests for variable: WTCLASS

NOTE: This test controls the type I experimentwise error rate but generally has a higher type II error rate than Tukey's for all pairwise comparisons.

Alpha= 0.05 Confidence= 0.95 df= 669 MSE= 82.60835
Critical Value of T= 2.94578

Comparisons significant at the 0.05 level are indicated by '***'.

AGECLASSW Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
4.5 - 5.5	-0.768	2.662	6.092	
4.5 - 3.5	-0.242	3.613	7.468	
4.5 - 2.5	3.064	6.730	10.397	***
4.5 - 1.5	13.646	17.228	20.809	***
4.5 - 0.5	29.050	32.994	36.938	***
5.5 - 4.5	-6.092	-2.662	0.768	
5.5 - 3.5	-2.513	0.951	4.415	
5.5 - 2.5	0.816	4.069	7.321	***
5.5 - 1.5	11.409	14.566	17.723	***
5.5 - 0.5	26.770	30.332	33.895	***
3.5 - 4.5	-7.468	-3.613	0.242	
3.5 - 5.5	-4.415	-0.951	2.513	
3.5 - 2.5	-0.580	3.118	6.815	
3.5 - 1.5	10.001	13.615	17.228	***
3.5 - 0.5	25.408	29.381	33.355	***
2.5 - 4.5	-10.397	-6.730	-3.064	***
2.5 - 5.5	-7.321	-4.069	-0.816	***
2.5 - 3.5	-6.815	-3.118	0.580	
2.5 - 1.5	7.085	10.497	13.909	***
2.5 - 0.5	22.474	26.264	30.054	***
1.5 - 4.5	-20.809	-17.228	-13.646	***
1.5 - 5.5	-17.723	-14.566	-11.409	***
1.5 - 3.5	-17.228	-13.615	-10.001	***
1.5 - 2.5	-13.909	-10.497	-7.085	***

0.5 1.5 2.5 3.5 4.5 5.5

Model: MODEL1
Dep Variable: WTCLASS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	12	109227.00114	9102.25010	113.126	0.0001
Error	675	54311.11669	80.46091		
C Total	687	163538.11783			
Root MSE		8.97000	R-Square	0.6679	
Dep Mean		52.45166	Adj R-Sq	0.6620	
C.V.		17.10146			

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > T
INTERCEP	1	25.451618	1.98857816	12.799	0.0001
MALE	1	0.755993	1.55396343	0.486	0.6268
AGECLASS	1	16.216769	1.25034550	12.970	0.0001
AGESQ	1	-1.996274	0.22081903	-9.040	0.0001
YEAR84	1	-5.137231	1.56567190	-3.281	0.0011
YEAR85	1	-5.740243	1.45728802	-3.939	0.0001
YEAR86	1	-0.392618	1.51101993	-0.260	0.7951
YEAR87	1	-8.743988	1.56597052	-5.584	0.0001
YEAR88	1	-6.189797	1.33222596	-4.646	0.0001
YEAR89	1	-6.831968	1.42764473	-4.785	0.0001
YEAR91	1	2.629873	1.89896922	1.385	0.1665
YEAR92	1	8.258321	1.90827415	4.328	0.0001
MALEAGE	1	3.160594	0.47382791	6.670	0.0001

model w/out bobcat,
including ~~age~~ agesq.

Model: MODEL1
Dep Variable: WTCLASS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	11	102651.14582	9331.92235	103.608	0.0001
Error	676	60886.97202	90.06949		
C Total	687	163538.11783			
Root MSE		9.49049	R-Square	0.6277	
Dep Mean		52.45166	Adj R-Sq	0.6216	
C.V.		18.09379			

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > T
INTERCEP	1	35.825684	1.71831051	20.849	0.0001
MALE	1	0.933038	1.64400321	0.568	0.5705
AGECLASS	1	5.324391	0.35354492	15.060	0.0001
YEAR84	1	-5.084238	1.65651004	-3.069	0.0022
YEAR85	1	-6.200831	1.54090612	-4.024	0.0001
YEAR86	1	-0.583261	1.59854275	-0.365	0.7153
YEAR87	1	-10.506026	1.64395399	-6.391	0.0001
YEAR88	1	-6.404652	1.40930546	-4.545	0.0001
YEAR89	1	-6.003373	1.50736921	-3.983	0.0001
YEAR91	1	2.657879	2.00915623	1.323	0.1863
YEAR92	1	8.599437	2.01860903	4.260	0.0001
MALEAGE	1	3.297022	0.50106794	6.580	0.0001

Model: wtclass = male ageclass year84 year85 year86 year87
year88 year89 year91 year92

- model w/out bobcat included
ageseq

Model: MODEL1

Dep Variable: WTCLASS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	12	109227.00114	9102.25010	113.126	0.0001
Error	675	54311.11669	80.46091		
C Total	687	163538.11783			
Root MSE		8.97000	R-Square	0.6679	
Dep Mean		52.45166	Adj R-Sq	0.6620	
C.V.		17.10146			

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > T
INTERCEP	1	25.059000	1.91753957	13.068	0.0001
MALE	1	0.755993	1.55396343	0.486	0.6268
AGECLASS	1	16.216769	1.25034550	12.970	0.0001
AGESQ	1	-1.996274	0.22081903	-9.040	0.0001
BOBCAT	1	0.392618	1.51101993	0.260	0.7951
YEAR84	1	-4.744614	1.52063978	-3.120	0.0019
YEAR85	1	-5.347626	1.40716982	-3.800	0.0002
YEAR87	1	-8.351371	1.51507078	-5.512	0.0001
YEAR88	1	-5.797179	1.27706130	-4.539	0.0001
YEAR89	1	-6.439350	1.37332336	-4.689	0.0001
YEAR91	1	2.629873	1.89896922	1.385	0.1665
YEAR92	1	8.258321	1.90827415	4.328	0.0001
MALEAGE	1	3.160594	0.47382791	6.670	0.0001

Reduced Model

SAS

13:52 Friday, June 20, 1986 25

Model: MODEL1

Dep Variable: WTCLASS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	11	102651.14582	9331.92235	103.608	0.0001
Error	676	60886.97202	90.06949		
C Total	687	163538.11783			
Root MSE		9.49049	R-Square	0.6277	
Dep Mean		52.45166	Adj R-Sq	0.6216	
C.V.		18.09379			

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > T
INTERCEP	1	35.242423	1.64184330	21.465	0.0001
MALE	1	0.933038	1.64400321	0.568	0.5705
AGECLASS	1	5.324391	0.35354492	15.060	0.0001
BOBCAT	1	0.583261	1.59854275	0.365	0.7153
YEAR84	1	-4.500977	1.60862381	-2.798	0.0053
YEAR85	1	-5.617570	1.48848709	-3.774	0.0002
YEAR87	1	-9.922765	1.59239980	-6.231	0.0001
YEAR88	1	-5.821392	1.35116115	-4.308	0.0001
YEAR89	1	-5.420113	1.44810720	-3.743	0.0002
YEAR91	1	2.657879	2.00915623	1.323	0.1863
YEAR92	1	8.599437	2.01860903	4.260	0.0001
MALEAGE	1	3.297022	0.50106794	6.580	0.0001

Model: MODEL1
 Dep Variable: WTCLASS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	14	109419.75033	7815.69645	97.194	0.0001
Error	673	54118.36750	80.41362		
C Total	687	163538.11783			
Root MSE		8.96736	R-Square	0.6691	
Dep Mean		52.45166	Adj R-Sq	0.6622	
C.V.		17.09644			

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > T
INTERCEP	1	25.135958	1.95222134	12.876	0.0001
MALE	1	0.277646	1.58468609	0.175	0.8610
AGECLASS	1	16.313891	1.25835949	12.964	0.0001
AGESQ	1	-2.007523	0.22101890	-9.083	0.0001
BOBCAT	1	-0.734946	2.99965233	-0.245	0.8065
YEAR84	1	-4.751534	1.52021383	-3.126	0.0019
YEAR85	1	-5.345219	1.40692386	-3.799	0.0002
YEAR87	1	-8.309105	1.51686547	-5.478	0.0001
YEAR88	1	-5.756228	1.27856935	-4.502	0.0001
YEAR89	1	-6.488948	1.37376307	-4.723	0.0001
YEAR91	1	2.669894	1.94631019	1.372	0.1706
YEAR92	1	8.462360	2.00285322	4.225	0.0001
MALEAGE	1	3.148820	0.47542253	6.623	0.0001
MALEBOB	1	2.629571	1.76787447	1.487	0.1374
BOBAGE	1	-0.123804	0.64820713	-0.191	0.8486

Model: MODEL1
 Dep Variable: WTCLASS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	13	102785.49907	7906.57685	87.717	0.0001
Error	674	60752.61877	90.13742		
C Total	687	163538.11783			
Root MSE		9.49407	R-Square	0.6285	
Dep Mean		52.45166	Adj R-Sq	0.6213	
C.V.		18.10062			

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > T
INTERCEP	1	35.457870	1.68061694	21.098	0.0001
MALE	1	0.563604	1.67743332	0.336	0.7370
AGECLASS	1	5.324595	0.36627205	14.537	0.0001
BOBCAT	1	-1.145013	3.17548064	-0.361	0.7185
YEAR84	1	-4.507957	1.60925490	-2.801	0.0052
YEAR85	1	-5.623631	1.48920760	-3.776	0.0002
YEAR87	1	-9.919320	1.59495489	-6.219	0.0001
YEAR88	1	-5.809531	1.35365334	-4.292	0.0001
YEAR89	1	-5.468681	1.44958250	-3.773	0.0002
YEAR91	1	2.831295	2.06054307	1.374	0.1699
YEAR92	1	8.961291	2.11969546	4.228	0.0001
MALEAGE	1	3.274840	0.50313264	6.509	0.0001
MALEBOB	1	2.283912	1.87127890	1.221	0.2227
BOBAGE	1	0.111845	0.68573042	0.163	0.8705

Model: MODEL1
Dep Variable: WTCLASS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	12	109227.00114	9102.25010	113.126	0.0001
Error	675	54311.11669	80.46091		
C Total	687	163538.11783			
Root MSE		8.97000	R-Square	0.6679	
Dep Mean		52.45166	Adj R-Sq	0.6620	
C.V.		17.10146			

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > T
INTERCEP	1	33.709938	2.18635557	15.418	0.0001
AGECLASS	1	16.216769	1.25034550	12.970	0.0001
AGESQ	1	-1.996274	0.22081903	-9.040	0.0001
MALE	1	0.755993	1.55396343	0.486	0.6268
YEAR84	1	-13.395552	1.90818508	-7.020	0.0001
YEAR85	1	-13.998564	1.81782412	-7.701	0.0001
YEAR86	1	-8.650938	1.86723719	-4.633	0.0001
YEAR87	1	-17.002309	1.89559016	-8.969	0.0001
YEAR88	1	-14.448117	1.70416284	-8.478	0.0001
YEAR89	1	-15.090288	1.78350368	-8.461	0.0001
YEAR90	1	-8.258321	1.90827415	-4.328	0.0001
YEAR91	1	-5.628448	2.17780477	-2.584	0.0100
MALEAGE	1	3.160594	0.47382791	6.670	0.0001

Model: MODEL1
 Dep Variable: WTCLASS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	11	109207.95800	9927.99618	123.529	0.0001
Error	676	54330.15983	80.37006		
C Total	687	163538.11783			
Root MSE		8.96493	R-Square	0.6678	
Dep Mean		52.45166	Adj R-Sq	0.6624	
C.V.		17.09180			

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > T
INTERCEP	1	34.099730	2.03310430	16.772	0.0001
AGECLASS	1	16.117771	1.23297823	13.072	0.0001
AGESQ	1	-1.997628	0.22067680	-9.052	0.0001
YEAR84	1	-13.395193	1.90710729	-7.024	0.0001
YEAR85	1	-13.992482	1.81675455	-7.702	0.0001
YEAR86	1	-8.638498	1.86600767	-4.629	0.0001
YEAR87	1	-16.970254	1.89337480	-8.963	0.0001
YEAR88	1	-14.466049	1.70280201	-8.495	0.0001
YEAR89	1	-15.080279	1.78237784	-8.461	0.0001
YEAR90	1	-8.237505	1.90671699	-4.320	0.0001
YEAR91	1	-5.600195	2.17580084	-2.574	0.0103
MALEAGE	1	3.366724	0.21198159	15.882	0.0001