IMPLICATIONS FOR THE INFLUENCE OF CAPTURE STRESS ON SELECTED DEMOGRAPHICS IN EASTERN WILD TURKEY HENS

By

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Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1994

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 2000

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ACKNOWLEDGEMENTS

I would like to offer my thanks to the Oklahoma Cooperative Fish and Wildlife Research Unit and the Oklahoma Department of Wildlife Conservation for their financial and logistical support of this project. I wish to express my sincere appreciation to my major advisor, Dr. Robert L. Lochmiller, for his advise, encouragement, expertise, and friendship during this project. I regret that Dr. Lochmiller was unable to see this project through to completion because of his untimely death, he will be greatly missed.

I would like to thank Dr. David M. Leslie, Jr. and Dr. Ronald E. Masters for their suggestions, comments, and advice throughout this project and especially for their unending assistance after Dr. Lochmiller's death. I would also like to offer thanks to Dr. James H. Shaw for serving as a graduate committee member with short notice. Additional thanks go to Mrs. Judy Gray for her clerical assistance, financial wisdom, and friendship.

I would like to offer thanks to the personnel of the Oklahoma Department of Wildlife Conservation, especially Mr. Jack Waymire, Mr. Leon Johnson, Mr. Bill Dinkines, and Mr. Ray Robinson for their assistance throughout this study. I would also like to sincerely thank the Waymire family (Jack, Eva, Al, and Dan) for their unending friendship, hospitality, and support. A sincere thanks also goes to our technicians Tom Gillham, Eric Webb, Brian Deason, and Brian Curley for their hard work and long hours spent in the field and to my 4700 hour students, especially Chris Deurmeyer, for their

hard work with the not so pleasant tasks in the lab. I would also like to thank all of the volunteers (too numerous to mention) who assisted with capture operations. Additional thanks go to Dr. Lochmiller's other graduate students during my tenure, for their friendship, assistance, and support during the long hours in the lab and office. A special thanks goes to Montie Stewart and Janet Dill for their assistance throughout the long field seasons.

I would like to offer sincere thanks to my mom, dad, and entire family for their love, support, and encouragement during this project and for instilling an appreciation of the outdoors into me at an early age. Without their love and support throughout life, I would have been unable to succeed.

Lastly, I would like to offer my deepest appreciation and thanks to my wife, Lori, whose continued support, unending encouragement, assistance in the lab and field, understanding, and mostly her undying love, contributed greatly to the completion of this project. I would also like to offer my gratitude to her for being so patient during my lengthy time spent in the field and for the late nights I spent in the lab and on the computer. To you I offer my deepest gratitude, appreciation, and love.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

Chapter II

Chapter III

LIST OF FIGURES

Figure Page

Chapter II

Chapter III

CHAPTER I

INTRODUCTION

This thesis is composed of 2 distinct manuscripts formatted for submission to a scientific journal. Each manuscript is complete as written and does not require any additional support material. Each chapter is formatted for the Journal of Wildlife Diseases. The order of arrangement for each manuscript is text, literature cited, tables, and figures.

CHAPTER II

RISK FACTORS ASSOCIATED WITH CAPTURE-RELATED DEATH IN EASTERN WILD TURKEY HENS

ABSTRACT: Capture-related mortality has been a notable risk in the handling of eastern wild turkey (Meleagris gallopavo silvestris). My objective was to evaluate how environmental factors influence risk and identify physiological correlates that could be used to identify susceptible birds. During winter (January - March) 1995-97, 130 eastern wild turkey hens were captured in southeastern Oklahoma and radiocollared. Of those, 20 hens died $\leq$ 14 days of capture. Serum creatine kinase activity (CK; $P < 0.01$), body temperature ($P < 0.01$), processing time ($P = 0.02$), and ambient temperature ($P < 0.01$) showed a positive relationship with mortality that occurred within 14 days of capture. Plasma corticosterone concentration ($P = 0.08$) and relative humidity ($P < 0.01$) showed a negative relationship with mortalities that occurred within 14 days post-capture. Stepwise logistic regression selected CK activity, relative humidity, and ambient temperature as the best predictors of mortality within 14 days post-capture. My data suggests that susceptible individuals may be identified from CK activity and that capture-related mortality may be minimized by establishing guidelines of when to curtail capture operations based on various weather conditions.

Key words: Aspartate aminotransferase, capture mortality, capture myopathy, creatine kinase, Meleagris gallopavo, plasma corticosterone, relative humidity, stress, temperature, wild turkey.

INTRODUCTION

Wild turkeys (Meleagris gallopavo) are routinely captured for trap and transplant programs and research purposes. With many capture routines, complications may occur during capture, which may lead to losses from capture myopathy (CM). Losses may occur during capture, transport, or after release, thereby influencing short-term survival. In some instances, mortalities that occur within 1 to 2 wk after release go undetected, ultimately influencing the success of some trap and transplant programs. In cases where mortalities are known, deaths of birds within 1 to 2 wk of capture may be related to capture (Campo et al., 1984; Kurzejeski et al., 1987; Godwin et al., 1991; Palmer et al., 1993; Chamberlain et al., 1996; Johnson et al., 1996; Miller et al., 1996), although the direct relationship between capture and death are often unknown.

Capture myopathy has been studied widely in mammals (Chalmers and Barrett, 1982; Beringer et al., 1996); however, relatively few studies have been conducted with birds (Bollinger et al., 1989; Dabbert and Powell, 1993), although capture myopathy has been documented in several avian species (Young, 1967; Windingstad et al., 1983; Carpenter et al., 1991), including wild turkeys (Spraker et al., 1987). Capture myopathy is a condition resulting from isotonic muscle contraction during restraint and handling that causes reduced blood flow to affected muscles (Spraker, 1982). It can lead to anaerobic metabolism and buildup of lactic acid within muscles that may result in lactic acidosis and cellular death. With increased cell permeability and cell lysis, increases in enzyme activity of creatine kinase (CK) and aspartate aminotransferase (AST) are often observed in serum, relative to skeletal and cardiac muscle necrosis (Chalmers and Barrett, 1982; Bollinger et al., 1989; Dabbert and Powell, 1993), with the activity of CK being the

most sensitive indicator of muscle damage in mammals (Chalmers and Barrett, 1982) and birds (Franson et al., 1985; Bollinger et al., 1989; Dabbert and Powell, 1993). However, this relationship has not been documented in wild turkeys.

Spraker et al. (1987) found that only 13 (22%) of 60 wild turkeys, captured and necropsied between 1980 and 1983, showed gross lesions characteristic of capture myopathy. However, upon microscopic examination, 30% of the birds had muscle lesions, with 96% of the 46 examined birds showing signs of microscopic skeletal muscle lesions. Of the birds with gross lesions, 73% were juveniles and 17% were adults, suggesting that juvenile turkeys may be more susceptible to capture myopathy. Spraker et al. (1987) noted that although many of those birds may have recovered following release, some may have been more susceptible to predation for several weeks following release.

My objective was to identify physiological and climatic factors that may help to predict the incidence of capture-related death in eastern wild turkey hens. I hypothesized that enzyme activity of CK and AST, and plasma corticosterone concentrations in the blood of turkeys at the time of capture would be predictive of risk of mortality within 14 days of capture.

MATERIALS AND METHODS

The study was conducted on the Pushmataha Wildlife Management Area (PWMA, Pushmataha County, Oklahoma, USA; 34°32'N, 95°21'W) located about 6 km south of Clayton, Oklahoma. The study area was in mountainous terrain along the western edge of the Ouachita Highland Province, and habitat types were similar to those

throughout most of southeastern Oklahoma (Duck and Fletcher, 1945). A detailed description of the study area was given by Masters (1991).

Wild turkey hens were captured using rocket nets at pre-baited sites during winter (January - March) 1995-97. On all but three trapping occasions, hens were placed in cardboard boxes and placed in the shade until they could be processed. When handling birds, a sock was placed over the head to calm the bird. Captured hens were fitted with a 90 g radio transmitter with a mortality sensor (3 to 4 hr delay; Lotek Engineering Inc., Ontario, Canada) that was attached by a backpack harness. Individually numbered leg-bands were attached to each bird. Turkeys were classified as juvenile or adult (Pelham and Dickson, 1992). Body mass (nearest 0.1 kg), body temperature (nearest 0.1 C), handling time (min), and ambient temperature (nearest 0.1 C) were recorded subsequent to release. I defined handling time as the elapsed time between firing of the net and release of the bird. Relative humidity at the time of capture was obtained from the Mesonet weather station (Oklahoma Climatological Survey, Norman, Oklahoma, USA) located about 9 km northeast of the study area (34°39'20"N, 95°19'33"W) where weather measurements were taken at 15-min intervals.

Blood samples were taken from the cutaneous ulnar vein using a 20-gauge needle and vacutainer (Becton Dickinson Vacutainer Systems, Rutherford, New Jersey, USA). Blood was collected into a 3-ml evacuated EDTA-K collection vial (Sherwood Medical, St. Louis, Missouri, USA) and a 10-ml evacuated serum-separating tube (Becton Dickinson Vacutainer Systems, Rutherford, New Jersey, USA). The birds were released at the capture site. Serum-separating tubes were centrifuged for 10 min at 1,000 rpm within 5 hr of capture, and serum was poured off into separate aliquots and stored at -80

C for future analysis. Serum samples showing marked signs of hemolysis were excluded from analysis. Activity of CK and AST in serum were determined by Vet Pro Laboratories (Tulsa, Oklahoma, USA) using a Technicon RA1000 chemistry analyzer (Bayer Diagnostics, Tarrytown, New York, USA), and plasma corticosterone concentrations were determined by Texas Veterinary Medical Diagnostic Laboratory (College Station, Texas, USA).

Hens were monitored daily following their release using a hand-held 3-element yagi antennae and portable scanning receiver (Lotek Engineering Inc., Ontario, Canada). Upon receiving a mortality signal, cause of death was determined as soon as possible (usually < 6 hr). Hens dying ≤ 14 days of capture were assumed to have died from capture-related stressors.

Comparisons were made to determine if there was differential susceptibility between adults and subadults to capture-related mortality using a likelihood ratio chi-square test (PROC UNIVARIATE; SAS Institute, Inc., 1990). Because of non-normal distributions, serum activity of CK and AST between hens that died ≤ 14 days of capture to those surviving >14 days of capture were compared using a Wilcoxon rank sum test (PROC NPAR1WAY; SAS Institute, Inc., 1990). Differences in plasma corticosterone concentrations, processing time, body temperature, ambient temperature, and relative humidity between groups were tested using analysis of variance (PROC GLM; SAS Institute, Inc., 1990). Univariate logistic regression procedures (PROC LOGISTIC; SAS Institute, Inc., 1990) were used to determine if selected variables were significant predictors of the probability of mortality ≤ 14 days of capture ($\underline{P}_m$). I then developed a multiple logistic regression model using stepwise forward selection of variables to

determine the model that best predicted mortality. Variables were allowed to enter the model when the $\log_e$ likelihood was deemed appropriate ($\underline{P} < 0.15$). Because observations with missing values were omitted by logistic regression procedures, initial analysis included all variables, and then variables that were not significant in the model and contained missing values were omitted and the analysis was repeated until the maximum number of observations was obtained.

RESULTS

During the three years of study, 130 hens were captured (111 adult, 19 subadult). Of the 130 hens captured, 20 (15%) died ≤14 days of capture (16 adult, 14%, and four subadult, 21%). Susceptibility of adults to mortality ≤14 days of capture did not differ from subadults ($\chi^2 = 0.511$, $\underline{df} = 1$, $\underline{P} = 0.48$); therefore, ages were pooled for further analyses. Of the hens that died ≤14 days of capture, mean number of days survived was 2.80 ± 0.62 (SE) and ranged from 0 to 9 days. Enzyme activity of CK was significantly higher for hens dying ≤14 days of capture compared with those surviving >14 days of capture ($\underline{P} < 0.01$; Table 1). Enzyme activity of AST ($\underline{P} = 0.15$) and plasma corticosterone concentration ($\underline{P} = 0.11$) did not differ between groups (Table 1). Handling time was longer ($\underline{F} = 8.78$; $\underline{df} = 1, 120$; $\underline{P} < 0.01$), body temperature greater ($\underline{F} = 9.57$; $\underline{df} = 1, 111$; $\underline{P} < 0.01$), ambient temperature greater ($\underline{F} = 12.69$; $\underline{df} = 1, 125$; $\underline{P} < 0.01$), and relative humidity lower ($\underline{F} = 15.92$; $\underline{df} = 1, 125$; $\underline{P} < 0.01$) for hens dying ≤14 days of capture (Table 1).

Univariate logistic regression indicated a positive relationship ($\chi^2 = 13.02$, $\underline{df} = 1$, $\underline{P} < 0.01$) between CK activity and $\underline{P}_m$ ≤14 days of capture (Fig. 1). No relationship was found between AST activity and $\underline{P}_m$ ($\chi^2 = 0.47$, $\underline{df} = 1$, $\underline{P} = 0.49$). Concentrations of

plasma corticosterone demonstrated a weak negative relationship with $\underline{P}_m$ ($\chi^2 = 3.02$, $\underline{df} = 1$, $\underline{P} = 0.08$; Fig. 1). Body temperature ($\chi^2 = 12.95$, $\underline{df} = 1$, $\underline{P} < 0.01$), processing time ($\chi^2 = 5.73$, $\underline{df} = 1$, $\underline{P} = 0.02$), and ambient temperature ($\chi^2 = 10.55$, $\underline{df} = 1$, $\underline{P} < 0.01$) were related positively to $\underline{P}_m$ (Fig. 1). Relative humidity demonstrated a strong negative relationship with $\underline{P}_m$ ($\chi^2 = 10.80$, $\underline{df} = 1$, $\underline{P} < 0.01$; Fig. 1).

Stepwise logistic regression selected CK activity ($\chi^2 = 3.32$, $\underline{P} = 0.07$), relative humidity ($\chi^2 = 4.85$, $P = 0.03$), and ambient temperature ($\chi^2 = 3.50$, $\underline{P} = 0.06$) as the best predictors of $\underline{P}_m \leq 14$ days of capture. The selected model ($\underline{P}_m = e^a / 1 + e^a$, where a = [-0.2466 + 0.000342 (CK) + 0.0870 (ambient temperature) - 0.0464 (relative humidity)]) predicted 52.9% of the deaths and 97.8% of the survivors correctly at a $\underline{P}_m \geq 0.5$, with the sensitivity of the model increasing to 58.8% at a $\underline{P}_m \geq 0.4$. Based on the predictive equation, $\underline{P}_m$ of hens dying ≤ 14 days of capture ranged from 0.019 to 0.988 ($\bar{\underline{x}} = 0.487 \pm 0.086$; $\underline{n} = 17$), and that of those surviving ranged from 0.01 to 0.65 ($\bar{\underline{x}} = 0.097 \pm 0.010$; $\underline{n} = 95$). Because of a strong correlation between CK activity and other capture-related variables, I removed CK activity from the model to determine which of the other variables were predictors of mortality within 14 days of capture. With CK excluded, relative humidity ($\chi^2 = 7.99$, $\underline{P} < 0.01$), ambient temperature ($\chi^2 = 1.48$, $\underline{P} = 0.22$), body temperature ($\chi^2 = 1.80$, $\underline{P} = 0.18$), and handling time ($\chi^2 = 2.68$, $\underline{P} = 0.10$) were included in the model. The model accurately predicted 61.1% of the deaths and 97.7% of the survivors at a $\underline{P}_m \geq 0.5$ with the sensitivity of the model increasing to 66.7% at a $\underline{P}_m \geq 0.4$ (Table 2). Based on the predictive equation, $\underline{P}_m$ of hens dying ≤ 14 days of capture ranged from 0.23 to 1.00 ($\bar{\underline{x}} = 0.84 \pm 0.06$; $\underline{n} = 18$) and that of surviving hens ranged from 0.06 to 0.98 ($\bar{\underline{x}} = 0.55 \pm 0.03$; $\underline{n} = 86$).

DISCUSSION

Previous studies indicated that juvenile turkeys may be more susceptible to capture- related death in winter (Spraker et al., 1987; Miller et al., 1996). Miller et al. (1996) reported that during winter capture (7 January to 4 March), 17% of the juvenile hens and 7% of adult hens died as a result of capture stress. I observed that 14% of adults and 21% of juveniles experienced mortality as a result of capture. Although a higher percentage of juveniles died within 14 days of capture, the difference was not significant in my study.

Environmental conditions have been linked to capture-related deaths in previous studies; however, these claims were not thoroughly tested. Bailey (1976) suggested that turkeys should not be trapped with temperatures >21.1 C, and Miller et al. (1996) suggested that winter trapping should only be conducted when temperatures are >15 C in Mississippi. In this study, a hen trapped at 15 C or 21.1 C had a $\underline{P}_m$ of 0.43 and 0.60, respectively, and at colder temperatures, $\underline{P}_m$ was lower. Therefore, I recommend not trapping turkeys when winter temperatures are >10 C (30% $\underline{P}_m$) in southeastern Oklahoma. In addition to ambient temperature, relative humidity and handling time should be considered important determinants of risk of mortality within 14 days of capture. Hens captured when relative humidity is < 40% are more susceptible to capture mortality, possibly as a result of more rapid dehydration, especially when ambient temperatures are elevated. Handling time should be kept to a minimum; $\underline{P}_m$ of hens released ≤1 hr of capture was ≤0.12. Many capture-related mortalities may be prevented by monitoring ambient temperature and relative humidity and adhering to guidelines of when to curtail trapping operations based on environmental variables. Additionally,

adequate personnel should be made available to minimize the subsequent handling time of wild turkeys after capture.

Although serum activities of CK and AST have been shown to be indicators of capture stress in mallards (Anas platyrhynchos) (Bollinger et al., 1989; Dabbert and Powell, 1993), their usefulness in turkeys has not been evaluated relative to capture myopathy. With respect to eastern wild turkeys, AST activity was not a good indicator of mortality risk. In this study, there may not have been adequate time for AST activity to become significantly elevated as mean handling time for all birds was 76 $\pm$ 37.7 min compared with a mean handling time of 106.1 min reported by Bollinger et al. (1989). Dabbert and Powell (1993) reported handling times of about 45 min which included transport from 4.8 to 12.9 km in a truck, which may have added to the elevated AST activities.

The activities of CK and AST are not thought to have diminished appreciably during the course of the collection, handling, and storage of serum in our study. Jones (1985b) noted no loss of CK activity and only 7% loss of AST activity in ovine plasma after four months of storage at -20 C. Similar observations were noted for blood plasma of cattle stored under similar conditions (Jones 1985a). Given that we stored samples for an average of 199 days (range 166 - 244 days) at -80 C and all samples were treated in a similar fashion during the study, we do not feel that loss of enzyme activity influenced the results of our study.

Plasma corticosterone has been demonstrated to be an effective measure of stress levels in domestic turkeys (Brown, 1961) and wild turkeys (Whatley et al., 1977). However, no previous work has been done on corticosterone levels and the incidence of

capture-related death in wild turkeys. There was a slight tendency for lower levels of plasma corticosterone to be associated with an increased risk of mortality within 14 days of capture, in this study. Although this relationship was not significant, it deserves further investigation. My initial hypothesis was that corticosterone levels would behave similarly to CK activity. The most logical explanation for this relationship is that hens that experience high levels of stress (high levels of plasma corticosterone) reach a state of shock and "freeze", thus minimizing the amount of skeletal and muscle damage (low CK activity). Conversely, those hens that experience lower levels of stress (low levels of plasma corticosterone), struggle more violently and therefore cause more muscle and skeletal damage (high CK activity). However, further study should be conducted to determine the direct relationship of plasma corticosterone and CK activity under these conditions.

Enzymatic profiles from this study could be useful in identifying individuals that may be at risk of post-release death from handling. Such information could be useful in planning and operating transplant programs, especially when birds have been obtained from other state agencies and a sizeable investment has been made in the birds. Blood is often collected for disease screening, therefore, a CK analysis could be easily performed at the same time for minimal cost. To help minimize the loss of wild turkeys as a result of capture, I suggest trapping turkeys when the ambient temperature is below 10 C and relative humidity is above 40%, in southeastern Oklahoma. Additionally, adequate personnel should be available to assist with handling birds such that handling time is minimized (preferably <1 hr). Similar studies should be conducted from other

geographic regions to determine critical environmental values such that capture-related deaths are minimized.

ACKNOWLEDGMENTS

I thank W. C. Dinkines, S. S. Ditchkoff, C. Deurmeyer, T. Gillham, S. A. Harmon, L. Johnson, L. L. Nicholson, J. Waymire, R. Webb, E. R. Welch, Jr, and the many other volunteers for their assistance in the field. Funding for this project was provided by the Oklahoma Department of Wildlife Conservation with funds from the Federal Aid in Wildlife Restoration Program (Project W-145-R) and the Oklahoma Cooperative Fish and Wildlife Research Unit (Oklahoma State University, Oklahoma Department of Wildlife Conservation, U.S. Geological Survey Biological Resources Division, and Wildlife Management Institute cooperating). Capture and handling procedures were approved by our Institutional Animal Care and Use Committee (protocol No. 462), Oklahoma State University.

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Table 1. Differences in selected factors associated with mortality and survival ≤14 days of capture for eastern wild turkey hens at Pushmataha WMA, Oklahoma, 1995-97. Differences were tested using Wilcoxon rank sum tests (CK and AST) and analysis of variance (all other variables).

	Capture Deaths			Survivors			
Variable	n	$\bar{x}$	SE	n	$\bar{x}$	SE	P-value
AST (IU/L)[a]	17	316	13	102	294	12	0.15
CK (IU/L)[b]	17	4,807	951	102	1,986	114	< 0.01
Corticosterone (ng/ml)	16	135.8	14.4	99	161.6	6.0	0.11
Body temp. (C)	18	42.4	0.4	95	41.0	0.2	< 0.01
Handling time (min)[c]	20	98.1	6.3	102	72.2	3.7	< 0.01
Ambient temp. (C)	20	6.9	1.7	107	0.8	0.7	< 0.01
Relative humidity	20	46.9	3.7	107	65.6	1.9	< 0.01

[a] Aspartate aminotransferase.

[b] Creatine kinase.

[c] Time elapsed from when the net was fired until the bird was released.

Table 2. Stepwise logistic regression model[a] accuracy for predicting mortalities ≤14 days of capture for eastern wild turkey hens at Pushmataha WMA, Oklahoma, 1995-97. Variables included in the model were relative humidity, ambient temperature, body temperature, and handling time. Accuracies were determined when the probability of mortality (P_m) was ≥0.5 and ≥0.4. Creatine kinase (CK) was excluded from analysis because of correlations with other variables.

	$P_m > 0.5$ predicts mortality		$P_m > 0.4$ predicts mortality	
Outcome	Mortalities	Survivors	Mortalities	Survivors
Actual observation	18	86	18	86
Predicted				
Mortalities	11	1	12	2
Survivors	7	100	6	99
Sensitivity (%)[b]	61.1		66.7	
Specificity (%)[c]	97.7		97.7	

[a] $P_m = e^a / 1 + e^a$, where a = [-17.3651 + 0.4241 (body temperature) + 0.0659 (ambient temperature) - 0.0577 (relative humidity) + 0.0166 (handling time)].

[b] Proportion of mortalities ≤14 days of capture that are predicted to be mortalities.

[c] Proportion of hens surviving >14 days that are predicted to survive.

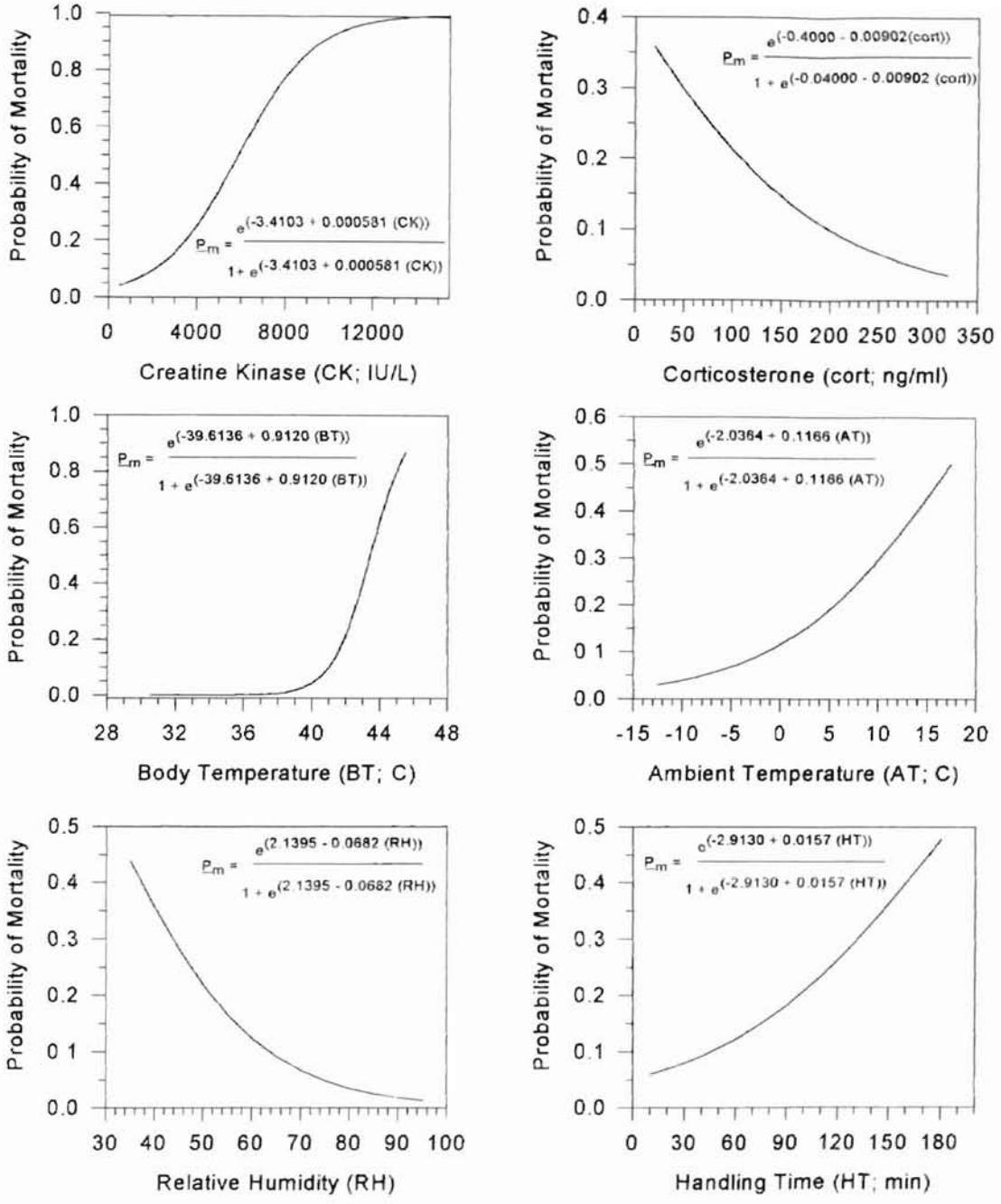

Figure 1. Relationships between creatine kinase (CK), plasma corticosterone (cort), body temperature (BT), handling time (HT), ambient temperature (AT), and relative humidity (RH) as related to the probability of mortality ($\underline{P}_m$) ≤14 days post-capture for eastern wild turkey hens at Pushmataha WMA, Oklahoma, 1995-97. Values calculated using predictive equations derived from univariate logistic regression models ($\underline{P} \leq 0.08$).

CHAPTER III

IMPLICATIONS FOR THE INFLUENCE OF CAPTURE STRESS ON SELECTED DEMOGRAPHICS IN EASTERN WILD TURKEY HENS.

ABSTRACT: Information on the demographics of eastern wild turkey hens (Meleagris gallopavo silvestris) in southeastern Oklahoma was needed to evaluate recent population declines. My objective was to document demographic parameters and determine if capture stress had a detrimental impact on those parameters. During winter (January - March) 1995-97, 130 eastern wild turkey hens were captured and radiocollared. Kaplan-Meier annual survival estimates ranged from 48.2% - 59.7% during the 3 years, with survival being the lowest during the nesting season. Nest initiation rates averaged 87.2% with overall nest success ranging from 19.3 - 23.1%. Juvenile hens weighing less at capture were less likely to initiate a nest. Renesting rates averaged 54.4%; hens weighing less at capture were less likely to renest ($P = 0.03$). Aspartate aminotransferase (AST) activity was related negatively to the success of a first nest attempt ($P = 0.04$), and creatine kinase (CK) activity tended to be related negatively to renesting rates ($P = 0.08$). AST activity was correlated positively with the date of nest initiation ($P = 0.03$), and hens trapped later in the trapping period were more likely to delay nest initiation ($P = 0.02$). Low nesting success and poult survival may be responsible for the decline in turkey numbers in this region; however, capture stress may have impacted reproductive success. Further study should be conducted to determine specific levels of influence that capture and radio-instrumentation have on free ranging wild turkeys.

Key words: Aspartate aminotransferase, capture, corticosterone, creatine kinase, handling time, Meleagris gallopavo silvestris, nest success, reproduction, stress, survival, wild turkey.

INTRODUCTION

Wild turkeys were virtually extirpated from Oklahoma in the mid-1940's due to overhunting and habitat loss (Masters and Thackston, 1985). Beginning in 1973 and continuing through 1980, free-ranging eastern wild turkeys (Meleagris gallopavo silvestris) were trapped, translocated, and later released throughout Oklahoma, which successfully restored populations to historic ranges. Three release sites were used in Pushmataha County, Oklahoma, during 1977-1980, and by the end of 1980, population levels permitted an increase in hunter success (Thackston, 1980); harvest peaked in the late 1980s and early 1990s (Dinkines and Smith, 1993). Beginning in the early to mid-1990s, harvests began to decline (27% decrease in harvest from 1992 to 1993; Dinkines and Smith, 1993). Although demographics of reintroduced and expanding populations of eastern wild turkeys have been studied (McMahon and Johnson, 1980; Porter, 1978; Campo et al., 1984; Clark, 1985; Miller, 1990; Kulowiec and Haufler, 1985; McGuiness et al., 1990; Palmer et al., 1993; Vangilder and Kurzejeski, 1995; Chamberlain et al., 1996), data regarding declining populations in this region were lacking.

A major assumption associated with most radiotelemetry studies is that capture and tagging does not alter study animal behavior such that information gathered is not reflective of the population under study (Cowardin et al., 1985). Violations of that assumption could lead to erroneous interpretations of the data, especially when the violation goes unrecognized. Previous studies have shown that this assumption may have

been violated with several avian species (American woodcock [Scolopax minor]: Ramakka, 1972; red grouse [Lagopus lagopus scoticus]: Lance and Watson, 1977; willow grouse [Lagopus lagopus]: Erikstad, 1979; spruce grouse [Canachites canadensis franklinii]: Herzog, 1979; canvasbacks [Aythya valisineria]: Perry, 1981; ring-necked pheasants [Phasianus colchicus]: Warner and Etter, 1983; Columbian sharp-tailed grouse [Tympanuchus phasianellus columbianus]: Marks and Marks, 1987; common murres [Uria aalge]: Wanless et al., 1988; greater prairie chicken [Tympanuchus cupido]: Burger et al., 1991; mallards [Anas platyrhynchos] and wood ducks [Aix sponsa]: Pietz et al., 1993; chinstrap penguins [Pygoscelis antarctica]: Croll et al., 1996).

Recent studies have suggested that capture and radio-instrumentation of wild turkey hens may compromise reproductive success and survival, especially during the first year of capture and radio-instrumentation (Miller, 1990; Weinstein et al., 1995; Lopez and Peterson, 1997). Weinstein et al., (1995) suggested that previous studies using hens captured by rocket nets and radio-instrumented may have underrepresented true values of reproductive success, especially during the first year. Although Weinstein et al. (1995) did not attribute the cause to the capture process or radio-instrumentation, Nenno and Healy (1979) found that attachment of backpack harness radiotransmitters to human-imprinted wild turkey hens caused no behavioral changes after about 8 days post-instrumentation. Nenno and Healy (1979), therefore, concluded that radio-packages did not introduce serious bias into radiotelemetry studies of wild turkeys. In contrast, Miller (1990) found that radio-instrumentation appeared to have a negative influence on turkey survival within 108 days post-release, but capture was identified as an additional stress factor that may have contributed to the decreased survival. Therefore, it may be

concluded that the influence of capture stress may be a causal agent in decreased reproductive success, assuming that effects of radio-packages on human-imprinted turkeys are not significantly different than effects on free-ranging turkeys. Previous work has shown that certain variables were predictive of levels of capture stress in relation to deaths occurring within 14 days of capture (Nicholson et al., 2000). Therefore, I assume that these same variables would be indicative of the level of capture stress for hens surviving >14 days post-capture. Based on this information, I hypothesized that those hens experiencing higher levels of stress at the time of capture would show decreased survival or reproductive parameters compared with those experiencing lower levels of capture stress, if it was the causal agent for reductions in selected parameters.

STUDY AREA

The study was conducted on the Pushmataha Wildlife Management Area (PWMA), Pushmataha County (34°32'N, 95°21'W) located about 6 km south of Clayton, Oklahoma, USA and surrounding properties. The study area was in mountainous terrain along the western edge of the Ouachita Highland Province and habitat types throughout these areas are considered to be similar to habitat types throughout most of southeastern Oklahoma (Duck and Fletcher 1945). The major habitat type on PWMA is the oak-pine (Quercus spp. - Pinus spp.) type. The overstory is dominated by postoak (Q. stellata), shortleaf pine (P. echinata), blackjack oak (Q. marilandica), and hickory (Carya spp.). Dominant understory plants include flowering dogwood (Cornus floridanus), blueberry (Vaccinium spp.), blackberry (Rubus spp.), little bluestem (Schizachyrium scoparium), broomsedge (Andropogon virginicus), and panicums (Dicanthelium spp., Panicum spp.). Dominant woody vines include poison ivy (Toxicodendron radicans), greenbriar (Smilax

spp.), Virginia creeper (Parthenocissus quinquefolia), and grape (Vitis spp.). A more detailed description of the study area is given by Masters (1991).

METHODS

Wild turkey hens were captured using rocket nets at pre-baited sites during winter (January - March) 1995-97. On all but three trapping occasions, hens were placed in cardboard boxes and placed in the shade until they could be processed. When handling birds, a sock was placed over the head to calm the bird. Captured hens were fitted with a 90-g radio-package with a mortality sensor (3-4 hr delay; Lotek Engineering Inc., Ontario, Canada) that was attached by a backpack harness (Everett et al., 1978). Individually numbered leg-bands were attached to each bird. Turkeys were classified as juvenile or adult (Pelham and Dickson, 1992). Body mass (nearest 0.1 kg), body temperature (nearest 0.1 C), handling time (min.), and ambient temperature (nearest 0.1 C) were recorded subsequent to release. We defined handling time as the elapsed time between firing of the net and release of the bird. Relative humidity at the time of capture was obtained from the Mesonet weather station (Oklahoma Climatological Survey, Norman, Oklahoma, USA) located about 9 km northeast of the study area (34°39'20"N, 95°19'33"W) where weather measurements were taken at 15-min intervals.

Blood samples were taken from the cutaneous ulnar vein using a 20-gauge needle and vacutainer (Becton Dickinson Vacutainer Systems, Rutherford, New Jersey, USA). Blood was collected into a 3-ml evacuated EDTA-K collection vial (Sherwood Medical, St. Louis, Missouri, USA) and a 10-ml evacuated serum-separating tube (Becton Dickinson Vacutainer Systems, Rutherford, New Jersey, USA). Birds were released at the capture site. Serum-separating tubes were centrifuged for 10 min at 1,000 rpm within

5 hr of capture, and serum was poured off into separate aliquots and stored at -80 C for future analysis. Serum samples showing marked signs of hemolysis were excluded from analysis. Activity of creatine kinase (CK) and aspartate aminotransferase (AST) in serum were determined by Vet Pro Laboratories (Tulsa, Oklahoma, USA) using a Technicon RA1000 chemistry analyzer (Bayer Diagnostics, Tarrytown, New York, USA), and plasma corticosterone concentrations were determined by Texas Veterinary Medical Diagnostic Laboratory (College Station, Texas, USA). Whole blood was used for the immediate preparation of thin-film blood smears using the two microscope slide wedge technique described by Dein (1984). Thin film blood smears were stained with Diff Quik (Scientific Products Div., McGaw Park, IL), and differential leukocyte counts were performed (Dein, 1984). Heterophil/lymphocyte ratios were then calculated (Gross and Siegel, 1983).

Hens were monitored at least biweekly between August and September and at least twice daily from January through July using a hand-held 3-element yagi antennae and portable scanning receiver (Lotek Engineering Inc., Ontario, Canada). Upon receiving a mortality signal, cause of death was determined as accurately as possible based on field sign left at the transmitter recovery site, and time of death was recorded to the nearest time possible. During the nesting season (April-July) when radio signals indicated a mortality, the hen was assumed to be nesting and was checked remotely $\geq$4 times daily for 5 days. If no movement was indicated, an investigation of the area was made with the aid of binoculars from $\geq$40 m. If no signs of death were observed (e.g., feathers, bones, etc.), we left the area and continued intensive monitoring. If no activity

was detected for the remainder of the incubation period (28 days), we searched the area to determine cause of death.

Estimates of annual survival were calculated using the Kaplan-Meier staggered entry approach as described by Pollock et al. (1989). Annual survival rates were compared between years and ages using a Z-test (Pollock et al., 1989). Annual survival curves between years and ages were compared using a log-rank test (Pollock et al., 1989). Censored animals were included in the calculation of survival rates until the date of disappearance. Hens that did not survive 14 days post-capture were excluded from survival analysis.

Starting in April and continuing through July (i.e., nesting), we attempted to locate hens 3 times daily to determine nesting status. When hens began incubation (mortality signal), we approached the nest to about 50 m to minimize disturbance and flagged the perimeter of the nest location. Fate of nests was determined when radio-signals indicated that the hen was permanently off the nest (> 24 hr). A nest where at least one egg hatched was classified as successful, with abandoned or predated nests being classified as unsuccessful. The number of eggs hatched was determined by examination of eggshells at the nest site (Vangilder, 1992).

Nest success was calculated as the proportion of nests where at least one egg hatched and may have been overestimated because we may not have detected a nesting attempt that was destroyed or abandoned before incubation occurred. Nest initiation dates were defined as the first day of continuous incubation. Nest initiation rate was calculated as the number of hens available to nest that actually nested. Of those hens not nesting, only hens surviving to the last nest initiation date were included; hens that were

missing during any part of the nesting season were excluded. Renesting rate was defined as the proportion of hens establishing a second nest after surviving an unsuccessful first nest. G-tests (PROC FREQ; SAS Institute, Inc., 1988) were used to assess differences in nest success, renest success, nesting rate, and renesting rate between years and ages. Median tests (PROC FREQ; SAS Institute, Inc., 1988) were used to assess differences in nest initiation dates between years, ages, and successful versus unsuccessful nests.

Brood survival was determined by flushing and calling (Kimmel and Tzilkowski, 1986; Vangilder and Kurzejeski, 1995) the hen and brood close enough to get an accurate count at 2- and 4-weeks post-hatch. Poult survival could not be monitored beyond 4-weeks due to the formation of brood flocks by multiple hens. If a hen was observed in close proximity to another hen at 2- or 4-weeks post-hatch, that observation was excluded from the analysis of poult survival. Poult survival was calculated as the number of poults alive at 2- or 4-weeks post-hatch divided by the number of eggs that hatched.

Univariate logistic regression (PROC LOGISTIC; SAS Institute, Inc., 1990) and linear regression (PROC REG; SAS Institute, Inc., 1990) procedures were used to assess the influence of capture stress on survival and reproduction. Stress indicators (CK and AST activity, heterophil:lymphocyte ratios, and plasma corticosterone concentrations), climatic variables at the time of capture (ambient temperature and relative humidity), capture variables (handling time and date of capture), and hen characteristics (body mass, age, and body temperature) were used to determine the influence that capture may have had on reproduction and survival (> 14 days). Survival was divided into four periods: date of capture to mean first nest date (to nesting), day of capture to last nest date (through nesting), first nest date to last nest date (during nesting), and annual survival

(hens surviving $\leq$ 14 days were excluded from all analyses). Mortalities of hens during each period were compared with hens surviving the entire period in question using univariate logistic regression (PROC LOGISTIC; SAS Institute, Inc., 1990). Univariate logistic regression also was used to assess the influence of the various variables on whether or not a hen nested (of those surviving to the mean first nest date and again for those surviving to the last nest date), re-nested (of those surviving a 1st nest attempt and available to renest), and the success of 1st nests and renests. Univariate linear regression (PROC REG; SAS Institute, Inc., 1990) procedures were used to assess the influence the various variables had on nest initiation date, number of days between 1st nest and renesting, number of days a 1st nest survived, and the number of days a second nest survived. We then developed multiple logistic and linear regression models using stepwise forward selection of variables to determine the model that best predicted whether or not a hen nested, re-nested, the success of 1st nests and renests, nest initiation date, number of days between 1st nest and renesting, number of days a 1st nest survived, the number of days a second nest survived, survival from date of capture to mean first nest date, survival from day of capture to last nest date, survival from first nest date to last nest date, and annual survival. Variables were allowed to enter the model when the $\log_e$ likelihood was deemed appropriate ($P < 0.15$; Hosmer and Lemeshow, 1989; Sams et al. 1996; Cody and Smith 1997). Because observations with missing values were omitted by regression procedures, initial analysis included all variables, and then variables that were not significant in the model and contained missing values were omitted and the analysis was repeated until the maximum number of observations was obtained.

RESULTS

During the 3 years of study, 130 hens were captured (111 adult, 19 subadult). Of the 130 hens captured, 20 (15%) died ≤14 days of capture (16 adult, 14%, and four subadult, 21%) and were excluded from further analyses. Total annual radio-days for survival rate calculations were 4,556 in 1995, 10,408 in 1996, and 13,142 in 1997. Of the total sample size of 130 hens monitored for annual survival rates, 17 (12.7%) were censored (9 lost radio signal, 3 slipped harness, and 5 harnesses broke) and 50 (37.3%) died from various causes. Estimates of annual survival rates varied from 48.2% in 1995 to 59.7% in 1996 (Fig. 1). Sample sizes of juvenile hens were too low to enable testing for age-related differences in survival curves between years by log rank tests; however, Z-tests revealed no differences in annual survival rates between ages for 1995 ($P = 0.3607$) or 1996 ($P = 0.3927$). In 1997, there were only 2 juvenile hens in the sample; both survived through the year resulting in 100% survival. To increase sample size of juveniles, we combined years by age and found no differences in age-related survival rates ($P = 0.4689$; Fig. 2). Therefore, we combined age classes by year for further calculations of survival rate. Estimates of annual survival rates were not different between years ($P > 0.1794$), but survival curves differed between 1995 and 1996 ($P = 0.0088$) and between 1995 and 1997 ($P < 0.0001$). Survival curves did not differ between 1996 and 1997 ($P = 0.3011$). Predation was the predominant cause of mortality (86%) but some hens were lost to illegal kill (10%) and natural causes (4%).

Of 102 hens surviving to the beginning of the nesting season, 82 hens initiated a first nest attempt, 33 attempted a second nest, and 4 attempted a third nest (Table 1). Of the 102 hens surviving to the start of the nesting season, only 74 hens survived to the end

of the nesting season. Rates of nest-initiation did not differ between years ($\underline{P} = 0.584$) or ages ($\underline{P} = 0.139$). Initiation rates varied from 82.4% in 1995 to 90.9% in 1997. Overall rate of nest-initiation for years and ages combined was 87.2% (Table 2). Median nest-initiation dates ranged from 24 April to 10 May for all years (Table 3). Nest-initiation dates were later in 1996 than 1995 ($\underline{P} = 0.0097$) and 1997 ($\underline{P} = 0.0037$). The earliest incubation date was 8 April and the latest was 14 July (Fig. 3). Nest-initiation dates did not differ between successful and unsuccessful nests ($P > 0.05$); however, initiation dates in 1996 tended to be earlier for successful first nest attempts than unsuccessful first attempts ($\underline{P} = 0.086$). Regression analysis revealed that juvenile hens weighing more at time of capture initiated a nest earlier than those with lower body mass ($\underline{r}^2 = 0.4432$, $\underline{P} = 0.050$; Fig. 4). Nest initiation dates for adults were not correlated with body mass at time of capture ($\underline{P} > 0.05$). Nest success did not differ between years ($\underline{P} = 0.902$) but differed between ages ($\underline{P} = 0.003$; Table 1). Overall adult nest success (21/103 = 20.39%) was slightly lower than overall juvenile nest success (3/13 = 23.08%). Overall nest success was 19.3 - 23.1% during the 3 years of study.

Renesting rates differed between years ($\underline{P} = 0.002$) but not among ages ($\underline{P} = 0.143$). Caution should be taken when interpreting differences in age-related renesting rates due to low numbers of subadults available for renesting ($\underline{n} = 6$). Renesting rate was lowest in 1995 (45.5%) and highest in 1997 (64.7%; Table 2). Adult and juvenile hens weighing less at time of capture were less likely to renest after surviving an unsuccessful 1st nest ($\chi^2 = 4.62$, df = 1, P = 0.0317; Fig. 5).

Of the 24 successful nests, 198 poults were produced during the 3 years of study. Five of the 24 brood hens were killed within 2-weeks post-hatch; I assumed that broods

also were killed or died shortly thereafter because they were unable to fly. Sixty-five and 35 poults were known to survive to 2-weeks and 4-weeks post-hatch, respectively, in 3 years of study (Table 4). Poult survival was lower in 1995 than 1996 or 1997 ($\underline{P} < 0.001$) but did not differ between 1996 and 1997 for 2-week ($\underline{P} = 0.826$) or 4-week survival ($\underline{P} = 0.364$). Due to multiple brood formation, we were unable to distinguish broods of 3 hens during the 4th week count, and therefore, they were excluded from the calculation (1995, $\underline{n} = 1$; 1996, $\underline{n} = 1$; 1997, $\underline{n} = 1$).

Based on univariate logistic regression, CK and AST activity, heterophil: lymphocyte ratios, corticosterone concentrations, ambient temperature, relative humidity, date of capture, body mass, or body temperature were not significant predictors of a hen dying during the pre-defined periods, initiating a nest, or being successful on a renest attempt. Univariate logistic regression did indicate a positive relationship ($\chi^2 = 4.03$, $\underline{df} = 1$, $\underline{P} = 0.0446$) between AST activity and probability of an unsuccessful 1st nest (Fig. 6). CK activity demonstrated a slight negative relationship ($\chi^2 = 3.05$, $\underline{df} = 1$, $\underline{P} = 0.0810$) to the probability of a hen renesting after surviving a 1st nest attempt (Fig. 5). Based on univariate linear regression, CK and AST activity, heterophil:lymphocyte ratios, corticosterone concentrations, ambient temperature, relative humidity, date of capture, body mass, or body temperature were not related to number of days a 1st nest or renest survived, number of days between a 1st nest and renest, or number of days a hen survived. Univariate linear regression procedures indicated that AST activity was correlated positively ($\underline{F} = 4.73$, $\underline{df} = 1$, $\underline{P} = 0.0335$) with the date of nest initiation (Fig. 7). Additionally, hens trapped later in the trapping period (January - March) were more likely to delay nest initiation ($\underline{F} = 6.24$, $\underline{df} = 1$, $\underline{P} = 0.0150$; Fig. 8).

Stepwise logistic regression selected body mass ($\chi^2 = 3.46$, $\underline{df} = 1$, $\underline{P} = 0.0629$) and AST activity ($\chi^2 = 2.15$, df = 1, P = 0.1430) as the best predictors of a hen not renesting ($\underline{P}_{renest}$) after surviving an unsuccessful 1st nest attempt. The selected model ($\underline{P}_{renest} = e^a / 1 + e^a$, where a = [4.3354 - 1.4803 (body mass) + 0.00609 (AST)]) predicted 55.6% of those hens not renesting and 52.6% of those hens that renested correctly at a $\underline{P}_{renest} \geq 0.5$ with the sensitivity of the model increasing to 72.2% at a $\underline{P}_{renest} > 0.4$. Selected variables were not found to be significant in stepwise logistic regressions performed on the other parameters. Stepwise linear regression selected body mass ($\underline{F}$ = 7.85, $\underline{P} = 0.0075$), AST activity ($\underline{F}$ = 3.58, $\underline{P} = 0.0648$), body temperature ($\underline{F} = 2.24$, $\underline{P}$ = 0.1412), and day of capture ($\underline{F} = 10.78$, $\underline{P} = 0.0020$) as the best model ($\underline{r}^2 = 0.35$) for explaining date of nest initiation. Selected variables were not found to be significant in stepwise linear regressions performed on the other parameters.

DISCUSSION

Annual survival rates for the 3 years of study averaged 55.2 % (range 48.2 - 59.7%). Those rates were comparable to similar studies of eastern wild turkey hen survival in Missouri (45-69%; Vangilder and Kurzejeski, 1995), Mississippi (50-81%; Palmer et al., 1993), and Iowa (58-64%; Little et al., 1990). Although other studies are not directly comparable to this study due to calculation of survival rate, annual survival rates were similar (Porter, 1978, Campo et al., 1984, Holbrook and Vaughan, 1985, Vander Haegen et al., 1988). Although calculations of survival rate were not performed for a concurrent research project in the Ouachita Mountains, Arkansas, percent survival (number of hens that lived/total number of hens) was reported, and estimates averaged 64% in 1993-1996 (Johnson et al., 1996).

Predation was the major cause of mortality of wild turkey hens in this study. Similar findings were reported by Vangilder and Kurzejeski (1995) for 6 of 7 years in northern Missouri. In the Ouachita Mountains, predation was responsible for 59-80% of losses of adult hens (Johnson et al., 1996). Other studies also have reported predation as the leading mortality source of eastern wild turkey hens (Everett et al., 1980, Vander Haegen et al., 1988, Little et al., 1990, Palmer et al., 1993). Illegal kill was a significant source of mortality in 1995 (11.1%) and 1996 (13.0%); no hens were lost to poaching during 1997. This may have been a result of increased awareness of the turkey research project at Pushmataha WMA, and therefore, those results may be biased. Vangilder and Kurzejeski (1995) found that illegal kill ranged from 4 to 9% in 6 of 7 years of study, but in 1 year, illegal kill comprised 35% of known mortalities in northern Missouri. Losses from illegal harvest in the Ouachita Mountains averaged 2% and 27% for adult and subadult hens, respectively, between 1993 and 1996 (Johnson et al., 1996). Studies in Florida have found illegal kill to comprise $\leq$63% of hen loss during a fall gobbler hunting season on the Fisheating Creek WMA (Williams and Austin, 1988). Illegal kill also has been found to be a significant source of mortality in Kentucky (Wright and Speake, 1975), Alabama (Fleming and Speake, 1976), and Iowa (Little et al., 1990).

Hen survival was lowest during the nesting and brood-rearing seasons, as has been found in Iowa (Little et al., 1990). Lower survival rates during the nesting season have been found in Alabama (Speake, 1980, Everett et al., 1980), Minnesota (Porter, 1978), Massachusetts (Vander Haegen et al., 1988), and Mississippi (Palmer et al., 1993). Vangilder and Kurzejeski (1995) found lower survival rates during spring, but the lower survival was associated with spring break-up and not nesting and brood-rearing activities.

Although several studies have found differences in age-related survival of eastern wild turkeys (Porter, 1978, Vander Haegen et al., 1988, Little et al., 1990), I found no differential survival with respect to age. However, small samples of subadult hens may have hampered my ability to detect a difference. Survival rates in the Ouachita Mountains, Arkansas, were reported as 61% and 74% for adult and subadult hens, respectively, which were not significantly different (Johnson et al., 1995). Vangilder and Kurzejeski (1995) also found that there was no age-related difference in survival on a northern Missouri study area.

Nest-initiation rates averaged >82.4% for all 3 years of study, with the highest initiation rate (90.9%) in 1997. These rates are comparable to other studies of eastern wild turkey hens (Vangilder, 1992:145). In northern Missouri, nest-initiation rates were 91.5-100.0%; however, they used localized movements to determine nesting status, whereas I used 1st day of incubation. Using localized movements may overestimate nesting rates and use of incubation dates has been shown to underestimate nesting rates (Vangilder, 1992). Therefore, this may explain the lower rates found in this study. Nest initiation rates in the Ouachita Mountains ranged from 43 to 85% ($\bar{x}$ = 65%) for adults and 0 to 87% ($\bar{x}$ = 53%) for subadults (Johnson et al., 1996). No conclusive explanations have been determined for the lower nest-initiation rates in the Ouachita Mountain study compared with my study.

Median incubation begin dates ranged from 24 April to 7 May for adults and 4 May to 10 May for subadults. During the 3 years of study, 10% and 90% of hens had initiated incubation by 23 April and 25 May, respectively. Other studies have observed peak incubation dates ranging from 12 April in Mississippi (Hurst, 1988) to 10 May in

Minnesota (Porter, 1978). Vangilder and Kurzejeski (1995) found varying median incubation begin dates ranging from 28 April to 26 May during 7 years of study in north Missouri. They determined that colder temperatures in March were responsible in part for delays observed in nest incubation and lowered nest success. In Arkansas, mean incubation initiation dates varied from 24 April in 1995 to 18 May in 1993 during the 4 years of study (Johnson et al., 1996), which were similar to my findings.

I found higher renesting rates ($\bar{x}$ = 54.4%; range: 45.5 - 64.7%) than those found in similar studies (Williams and Austin, 1988, Vangilder and Kurzejeski, 1995, Johnson et al., 1996). In northern Missouri, renesting rates ranged from 14 to 75% ($\bar{x}$ = 40.6%; Vangilder and Kurzejeski, 1995), and in Arkansas, they ranged from 21 to 58% ($\bar{x}$ = 34.9%) for adults and 20 to 50% ($\bar{x}$ = 35.3%) for subadults (Johnson et al., 1996). The higher renesting rates found in this study were possibly a result of very low 1st nest success.

Nest success was similar between years ranging from 19.3 - 23.1%. Although these findings are not the lowest nesting success reported for the species, they are still lower than most other studies (Glidden and Austin, 1975, Everett et al., 1980, Hayden, 1980, Porter et al., 1983, Campo et al., 1984, Vander Haegen et al., 1988, Campo et al., 1989, Seiss et al., 1990, Vangilder and Kurzejeski, 1995). The only two studies that reported success rates lower than this study were in the Ouachita Mountains, Arkansas, where nest success ranged from 0 to 20% during 4 years of study (Johnson et al., 1996) and the Arkansas Ozarks where nest success averaged 17% for 2 years of study (Badyaev, 1994). Additionally, the study in the Ouachitas found that subadult hens contributed little to reproductive success (Johnson et al., 1996). In contrast, I found that

subadults had significantly higher nest success than adults, which may have been a reflection of the small samples of juveniles in my study.

Lower body weights in juvenile hens were correlated with later nest-initiation dates in my study. However, there was no relationship between adult body mass at time of capture and subsequent nest-initiation date. This may be an indication that juveniles are more susceptible to spring conditions than adults, or may just indicate a simple relationship of whether or not the hen was an early or late hatch the previous spring. In Minnesota, hens weighing <4.3 kg were found to have lower chances of survival and were less likely to nest than hens weighing more (Porter et al., 1983). In contrast, Schmutz and Braun (1989) found that heavier juvenile Rio Grande wild turkey (M. g. intermedia) hens in Colorado initiated nests later than lighter hens. No conclusive explanation has been found for differences in juvenile body-mass relationships with nest-initiation dates between PWMA and Colorado.

In most studies, poult survival was found to be the lowest in the first 2 weeks of life (Glidden and Austin 1975, Porter et al. 1983, Campo et al. 1984, Vangilder and Kurzejeski 1995). Poult survival at 2-weeks post-hatch varied from 27 to 47%, and survival to 4-weeks varied from 24 to 47% (Vangilder 1992:151). In the Ouachita Mountains, Arkansas, poult survival averaged 34.6% and 28.3% for 2- and 4-weeks post-hatch, respectively (Johnson et al., 1996), which is similar to that found on PWMA. However, in 1995, only 1 of 39 poults survived to 2-weeks post-hatch, suggesting that poult survival may be limiting during some years.

Roberts and Porter (1995), using population modeling techniques, determined that the most important factors influencing wild turkey populations were nest success,

juvenile-subadult-adult survival, and poult survival to 28 days post-hatch, respectively. Nest success alone explained 40% of the annual fluctuation in populations. Therefore, data from this study suggest that low nest success and during some years, low brood survival in southeastern Oklahoma, may have had a large influence on the population decline and suppression in this area.

However, data from this study also suggest that stress from capture may have impacted some of the reproductive parameters presented. Although AST activity was not found to be a significant predictor of wild turkey hens dying $\leq$14 days of capture (Nicholson et al., 2000), AST activity has been found to be an indicator of stress in other avian species (Franson et al., 1985; Bollinger et al., 1989; Dabbert and Powell, 1993) and has been used as an indicator of liver and muscle damage (Chalmers and Barrett, 1982; Allen, 1988). Hens experiencing higher AST activity levels at capture and those captured later in the capture period were more likely to delay nest initiation. Additionally, higher levels of capture stress as measured by AST activity negatively biased estimates of 1st nest success, and, therefore, the values reported may be lower than those of the population in general. Areas where hens are more successful earlier in the nesting season may exhibit a more pronounced effect of capture stress and time of capture on reproductive parameters.

Based on stepwise-regression procedures, hens in poorer health (i.e., low body mass) may show a more pronounced effect of capture stress on reproductive parameters Although body mass was not a significant predictor of hens dying within 14-days of capture (Nicholson et al., 2000) nor was years of mast failure related to capture-related mortality of hens in Mississippi (Miller et al., 1996). Data from my study suggest that

poor condition of hens coupled with stress of capture, may negatively influence reproductive parameters during the year of capture, which supports the findings of Weinstein et al. (1995). Thus, capture of hens during winters with low forage availability (i.e., mast failure) may result in a more pronounced bias of reproductive parameters that spring.

Activity of CK, which has been found to be a more sensitive indicator of muscle damage in birds (Franson et al., 1985; Bollinger et al., 1989; Dabbert and Powell, 1993), tended to be negatively related to the probability that a hen would renest after surviving a 1st nest attempt. Areas where renests contribute a significant part of overall reproductive success may exhibit a more dramatic effect of capture stress on overall reproductive success during the year of capture.

Although my study was not designed initially to test for effects of capture and radio-instrumentation on reproduction and survival, my data were used to test for capture related influences because of recent concerns (Miller, 1990; Weinstein et al., 1995; Lopez and Peterson, 1997). Data from my study suggest that higher levels of capture stress has a negative influence on reproductive parameters, especially when nest success is higher early in the nesting season or when a significant portion of reproductive success occurs from renests.

Using a simplistic population model constructed from mean survival and reproductive values from this study, I estimated a decline of about 25% in population levels between 1995-1997 (D. S. Nicholson, unpublished data), with the population becoming extirpated within about 25 years. However, spring harvest of males continued to increase on the study area (1995, $\underline{n} = 9$; 1996, $\underline{n} = 14$; 1997, $\underline{n} = 27$; 1998, $\underline{n} = 42$;) and

winter flock surveys conducted by Oklahoma Department of Wildlife Conservation (ODWC) personnel between January and February increased from 291 turkeys observed in 1995 to 791 turkeys observed in 1997 within Pushmataha County (Dinkines and Smith, 1998).

Additionally, of the radio-instrumented hens alive on 1 August each year, only 5%, 14%, and 16% had poults for each of the 3 years, respectively, compared to 65%, 39%, and 60% for each of the 3 years based on ancillary observations of hens on the study area between June and July (D. S. Nicholson, unpublished data) and 86%, 62%, and 78% for each of the 3 years based on summer brood surveys conducted between July and August by ODWC personnel for Pushmataha County (Dinkines and Smith, 1998). Poult to hen ratios were calculated based on the number of radio-instrumented hens alive on 1 August and the number of poults alive at 4-weeks post-hatch. Poult to hen ratios for radio-instrumented hens were 0.05, 0.57, and 0.88 poults/hen for each of the 3 years, respectively, compared to 1.96, 1.21, and 3.32 poults/hen for ancillary observations of hens between June and July for each of the 3 years (D. S. Nicholson, unpublished data) and 4.4, 3.3, and 4.6 poults/hen based on summer brood surveys conducted between July and August by ODWC personnel for Pushmataha County (Dinkines and Smith 1998). Values for radio-instrumented hens were conservative, because poults may have died between the 4-week count and 1 August, thus, poult to hen ratios may have been lower

The large discrepancies observed between radio-instrumented hens, ancillary observations of hens on the study area, and ODWC surveys and harvest reports suggest that the difference between demographic values for radio-instrumented hens and non-instrumented hens may have been greater than that found in this study. Radio-

instrumentation, the capture process in general (i.e., not necessarily the level of capture stress or muscle damage at time of capture), or an additive effect of the capture process and radio-instrumentation as suggested by Miller (1990), may have resulted in an even greater impact on demographic parameters than I found. Because of recent concerns (Miller, 1990; Weinstein et al., 1995; Lopez and Peterson, 1997) coupled with the results of this study, further detailed studies of the relationship between capture and radio-instrumentation of wild turkey hens on survival and reproduction should be conducted to determine the influence of each of these parameters, with recommendations to alleviate or minimize the negative impacts. Alternative capture and radio-instrumentation techniques should be explored to determine techniques that minimize adverse impacts.

ACKNOWLEDGMENTS

I thank W. C. Dinkines, S. S. Ditchkoff, C. Deurmeyer, T. Gillham, S. A. Harmon, L. Johnson, L. L. Nicholson, J. Waymire, R. Webb, E. R. Welch, Jr, and the many other volunteers for their assistance in the field. Funding for this project was provided by the Oklahoma Department of Wildlife Conservation with funds from the Federal Aid in Wildlife Restoration Program (Project W-145-R) and the Oklahoma Cooperative Fish and Wildlife Research Unit (Oklahoma State University, Oklahoma Department of Wildlife Conservation, U.S. Geological Survey Biological Resources Division, and Wildlife Management Institute cooperating). Capture and handling procedures were approved by our Institutional Animal Care and Use Committee (protocol No 462), Oklahoma State University.

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Table 1. Number of eastern wild turkey hens that attempted to nest and nesting success by year and age on Pushmataha Wildlife Management Area, Oklahoma, 1995-1997.

	1995				1996				1997			
	Adult		Subadult		Adult		Subadult		Adult		Subadult	
	n	% success	n	% success	n	% success	n	% success	n	% success	n	% success
Overall	15	13 3	5	40 0	34	23 5	5	20 0	54	20 4	3	0.0
1st attempt	10	20 0	4	50 0	24	20 8	4	25 0	38	26 3	2	0.0
2nd attempt	4	25 0	1	0 0	8	25 0	1	0.0	15	6 7	1	0.0
3rd attempt	1	0 0	0	0 0	2	50 0	0	0 0	1	0 0	0	0.0

Table 2. Nest-initiation rates and renesting rates for eastern wild turkey hens during 3 years on Pushmataha Wildlife Management Area, Oklahoma, 1995-1997.

	Initiation rate		Renest rate	
Year	No. hens nesting/ no. available nest	%	No. hens renesting/ no. available to renest	%
1995	14/16	87.5	5/11	45.5
1996	28/33	84.9	9/18	50.0
1997	40/44	90.9	11/17	64.7
Overall	82/93	88.2	25/46	54.4

Table 3. Median, and 10 and 90% quantiles of initiation of incubation for eastern wild turkey hens by year, nest attempt, and age during 3 years on Pushmataha Wildlife Management Area, Oklahoma, 1995-1997.

Nest attempt	Adult				Juvenile			
and year	n	Median	10%	90%	n	Median	10%	90%
First nests								
1995	10	25 April	22 April	9 May	4	10 May	25 April	10 June
1996	24	7 May	23 April	25 May	4	4 May	15 April	9 June
1997	38	24 April	12 April	10 May	2	6 May	5 May	6 May
Overall	72	29 April	17 April	18 May	10	6 May	20 April	10 June
Renests								
1995	6	24 May	29 April	14 July	1	13 June	13 June	13 June
1996	10	14 June	2 June	24 June	1	1 July	1 July	1 July
1997	17	3 June	22 May	16 June	1	2 June	2 June	2 June
Overall	33	6 June	19 May	23 June	3	13 June	2 June	1 July
All attempts								
1995	16	30 April	23 April	12 June	5	17 May	25 April	13 June
1996	34	12 May	23 April	18 June	5	10 May	15 April	1 July
1997	55	1 May	17 April	12 June	3	6 May	5 May	2 June
Overall	105	7 May	18 April	15 June	13	10 May	25 April	13 June

Table 4. Poult survival estimates (number of poults / number of hatched eggs) at 2-weeks and 4-weeks posthatch for wild turkey hens on Pushmataha Wildlife Management Area, Oklahoma, 1995-97.

	1995		1996		1997		Overall	
	Ratio[a]	%	Ratio[a]	%	Ratio[a]	%	Ratio[a]	%
2 week	1/39	2.6	24/58	44.3	40/101	39.6	65/198	32.8
4 week	*	*	18/52*	19.2	25/97*	25.8	35/149	23.5

[a] Number of poults / number of hatched eggs.

* At least one hen formed a multiple brood, and we were unable to get an individual poult count.

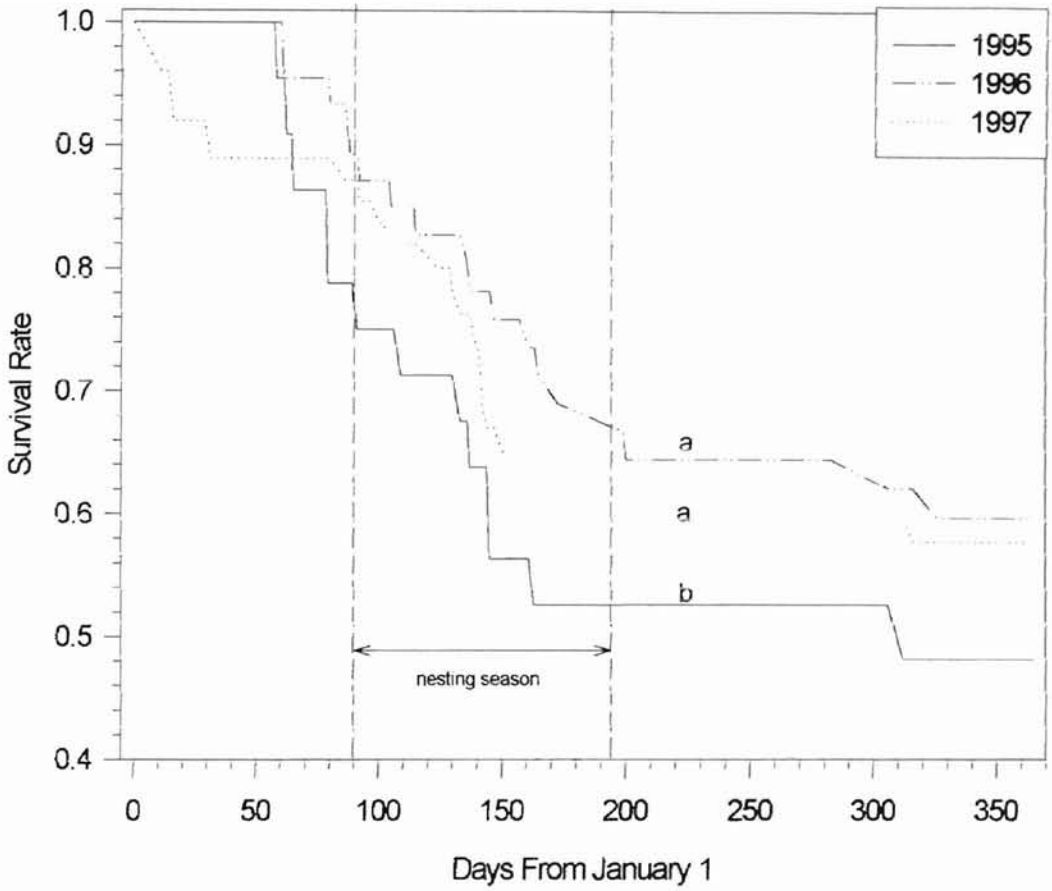

Figure 1. Kaplan-Meier survival rate estimates of eastern wild turkey hens (ages combined) at Pushmataha Wildlife Management Area, Oklahoma, for each of 3 years, 1995-97 (vertical dashed lines designate the average nesting season). Survival curves containing the same letter designation were not different ($P > 0.05$).

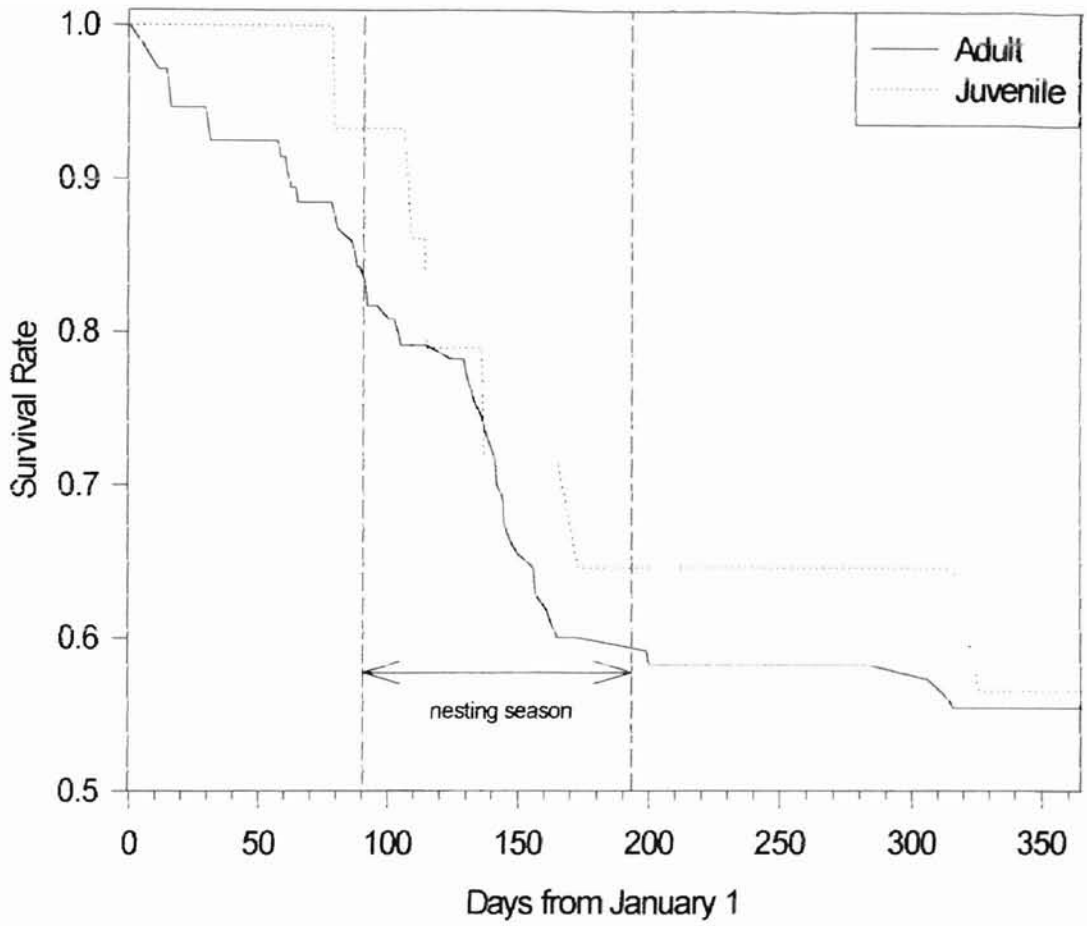

Figure 2. Kaplan-Meier survival rate estimates for adult and juvenile eastern wild turkey hens at Pushmataha Wildlife Management Area, Oklahoma, with years combined, 1995-97 (vertical dashed lines designate the average nesting season).

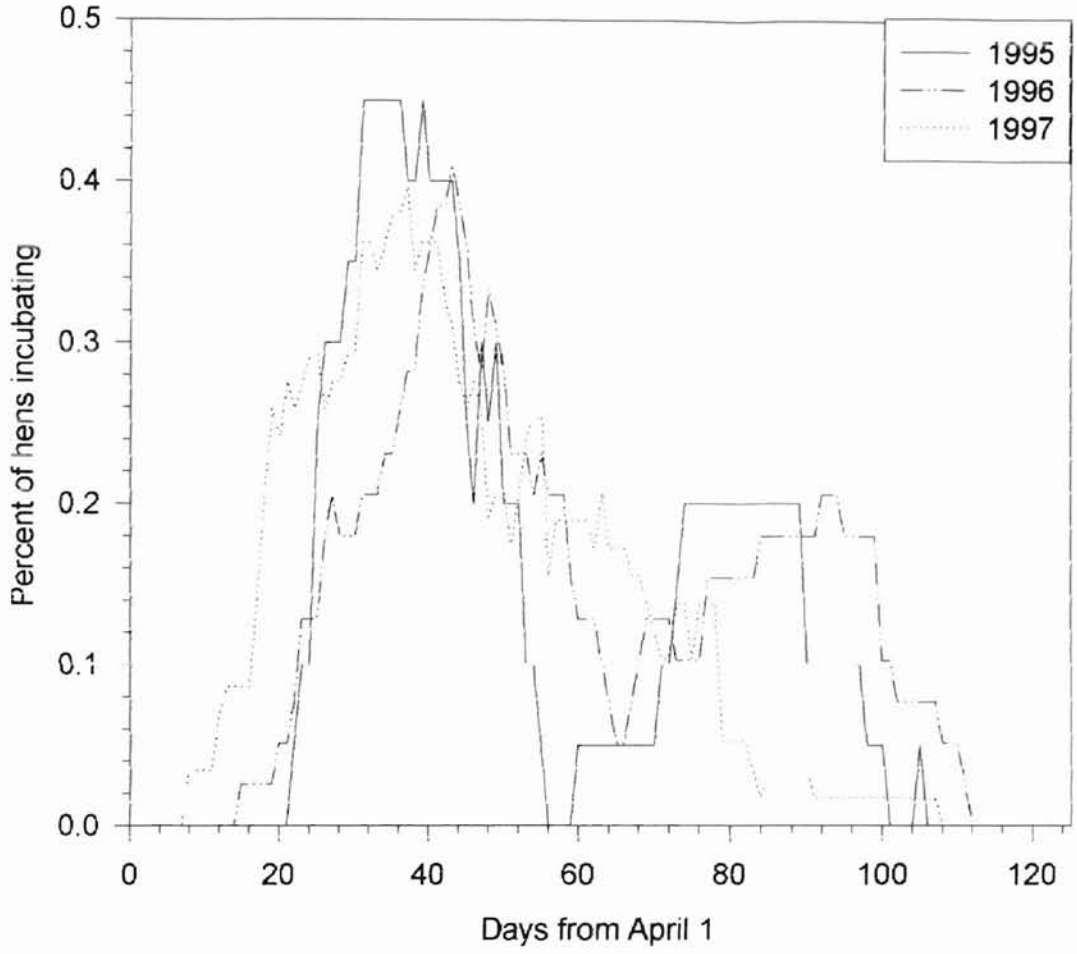

Figure 3. Percent hens (number of hens incubating on a given day / total number of nest attempts) incubating a nest from 1 April to 30 July for eastern wild turkey hens on the Pushmataha Wildlife Management Area, Oklahoma, 1995-1997.

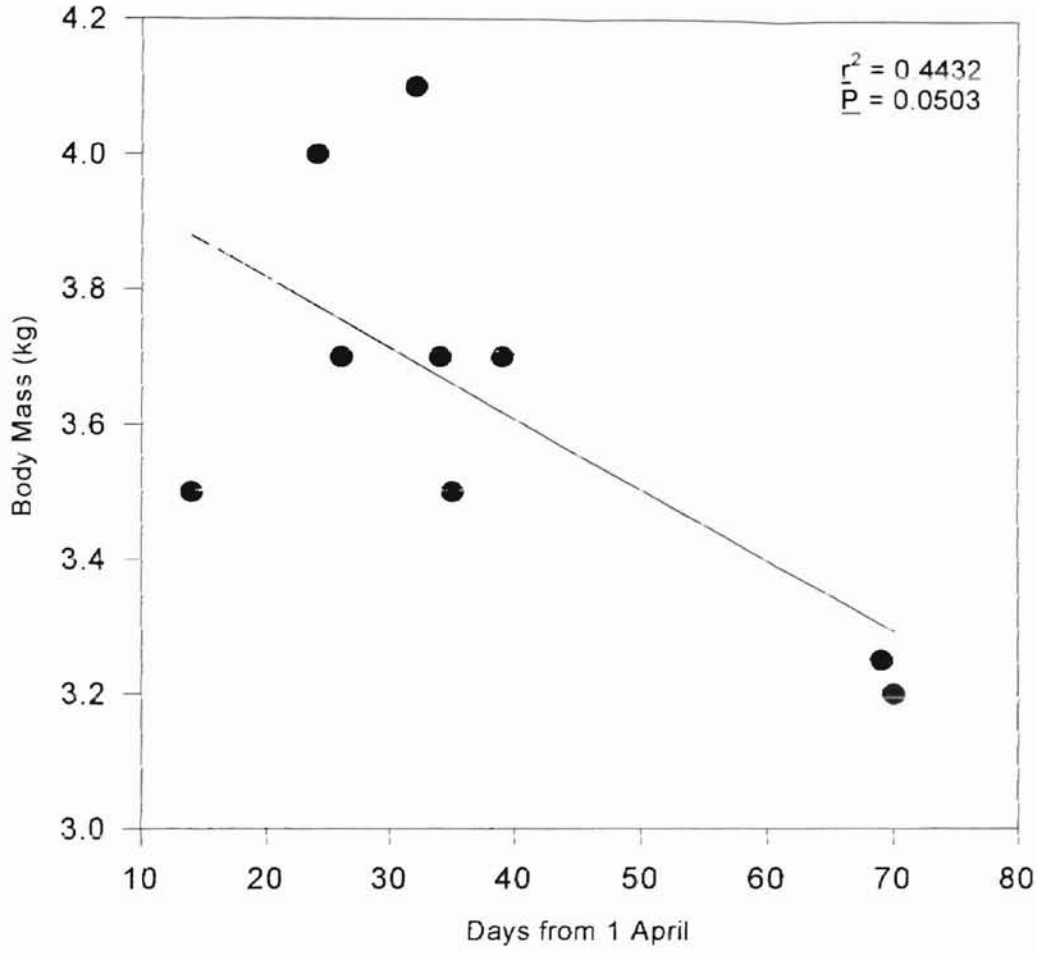

Figure 4. Least squares regression of nest-initiation date against body mass at time of capture for juvenile eastern wild turkey hens, Pushmataha Wildlife Management Area, Oklahoma, 1995-1997.

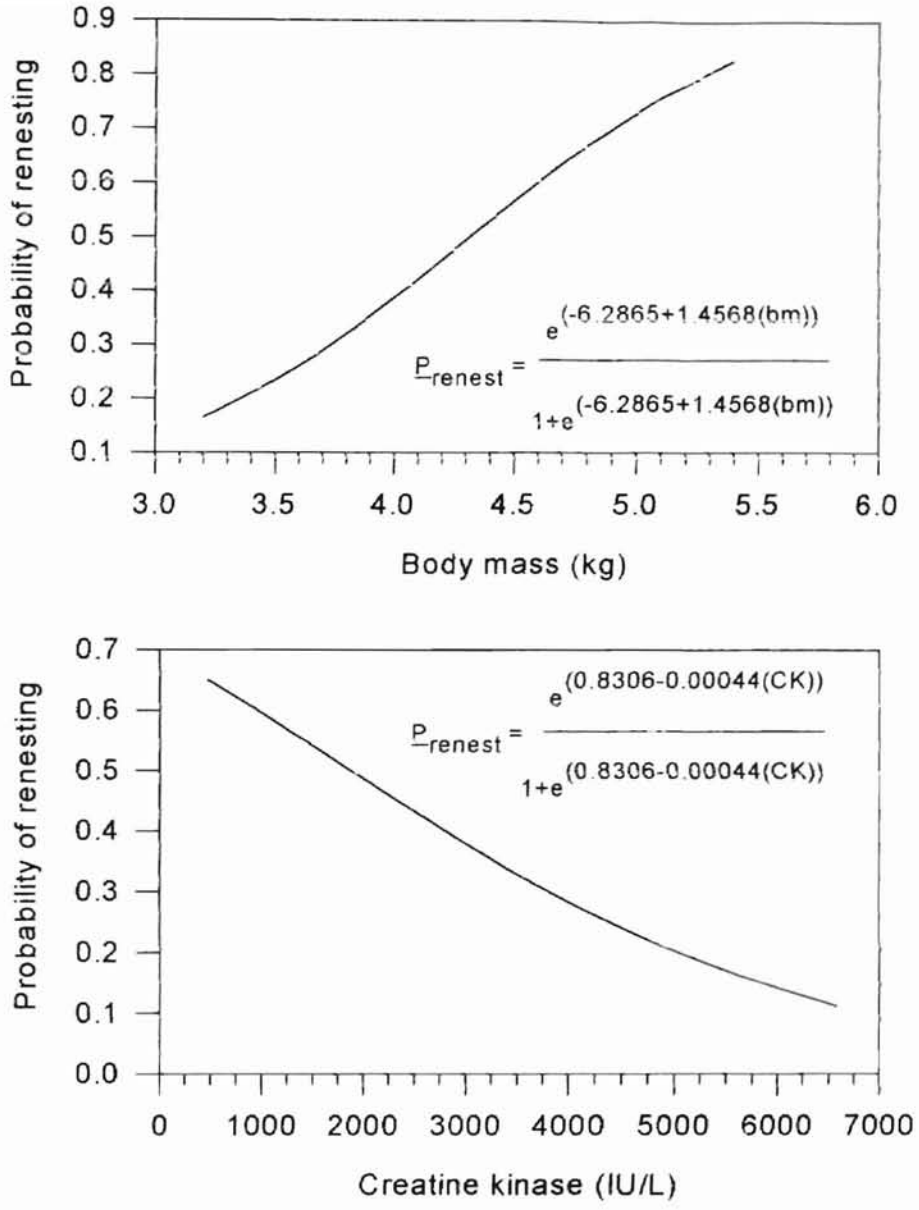

Figure 5. Relationship between body mass (bm) and creatine kinase (CK) activity at time of capture as related to the probability that a hen renests ($\underline{P}_{renest}$) after surviving an unsuccessful first nest attempt for eastern wild turkey hens at Pushmataha Wildlife Management Area, Oklahoma, 1995-97. Values calculated using predictive equation derived from univariate logistic regression models ($\underline{P} \leq 0.08$).

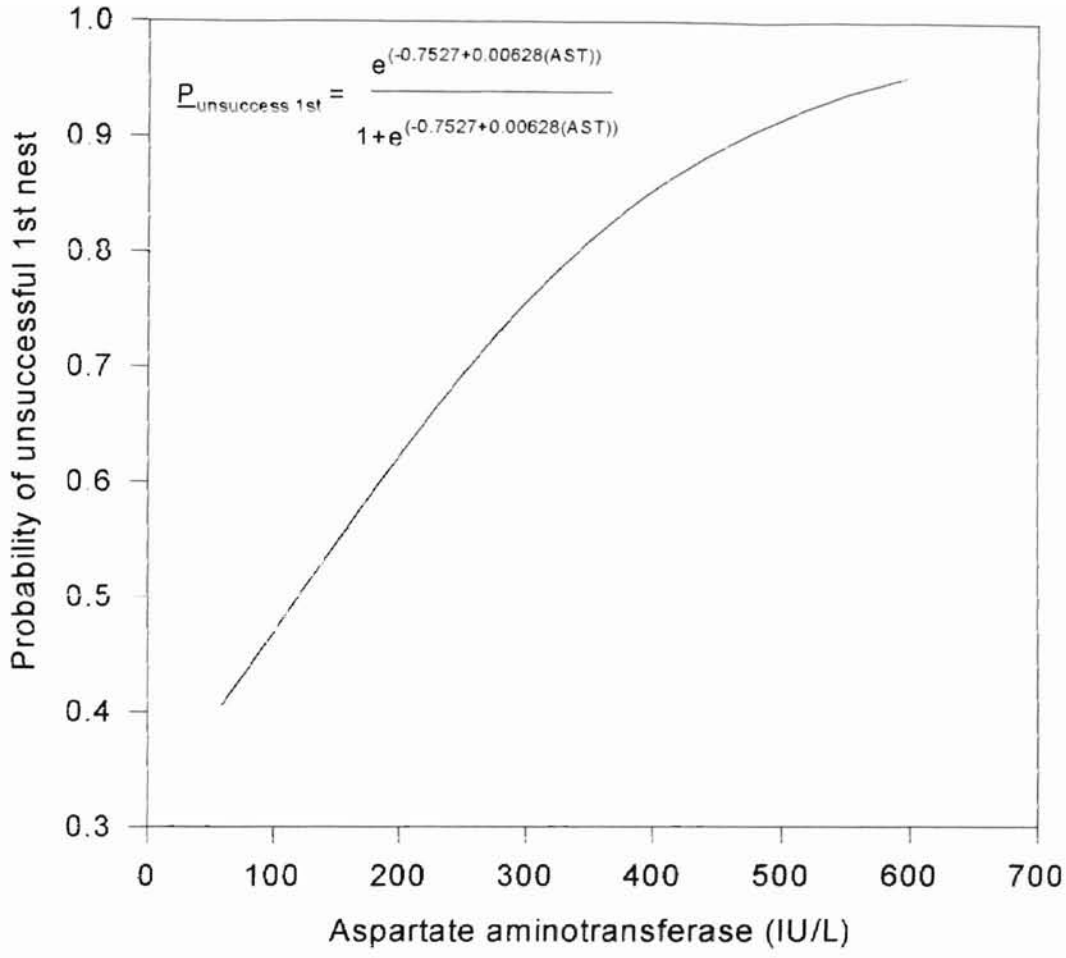

Figure 6. Relationship between aspartate aminotransferase (AST) activity at time of capture and the probability that a hen's first nest was unsuccessful ($\underline{P}_{unsuccess\ 1st}$) for eastern wild turkey hens at Pushmataha Wildlife Management Area, Oklahoma, 1995-97. Values calculated using predictive equation derived from univariate logistic regression model ($\underline{P} = 0.04$).

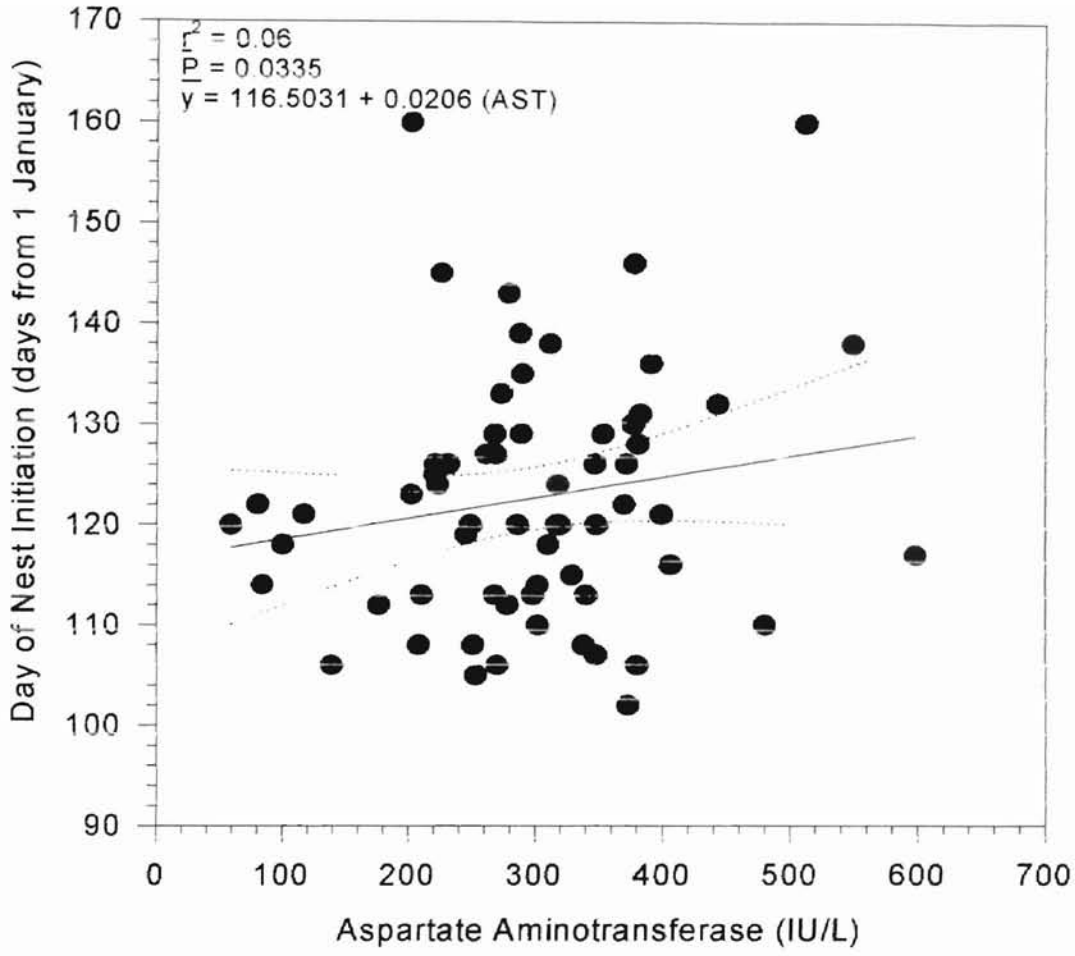

Figure 7. Relationship between aspartate aminotransferase (AST) activity and the date of first nest initiation (days from 1 April) for eastern wild turkey hens at Pushmataha Wildlife Management Area, Oklahoma, 1995-97. Values calculated using univariate linear regression model. Dotted lines designate the 95% confidence interval for the regression.

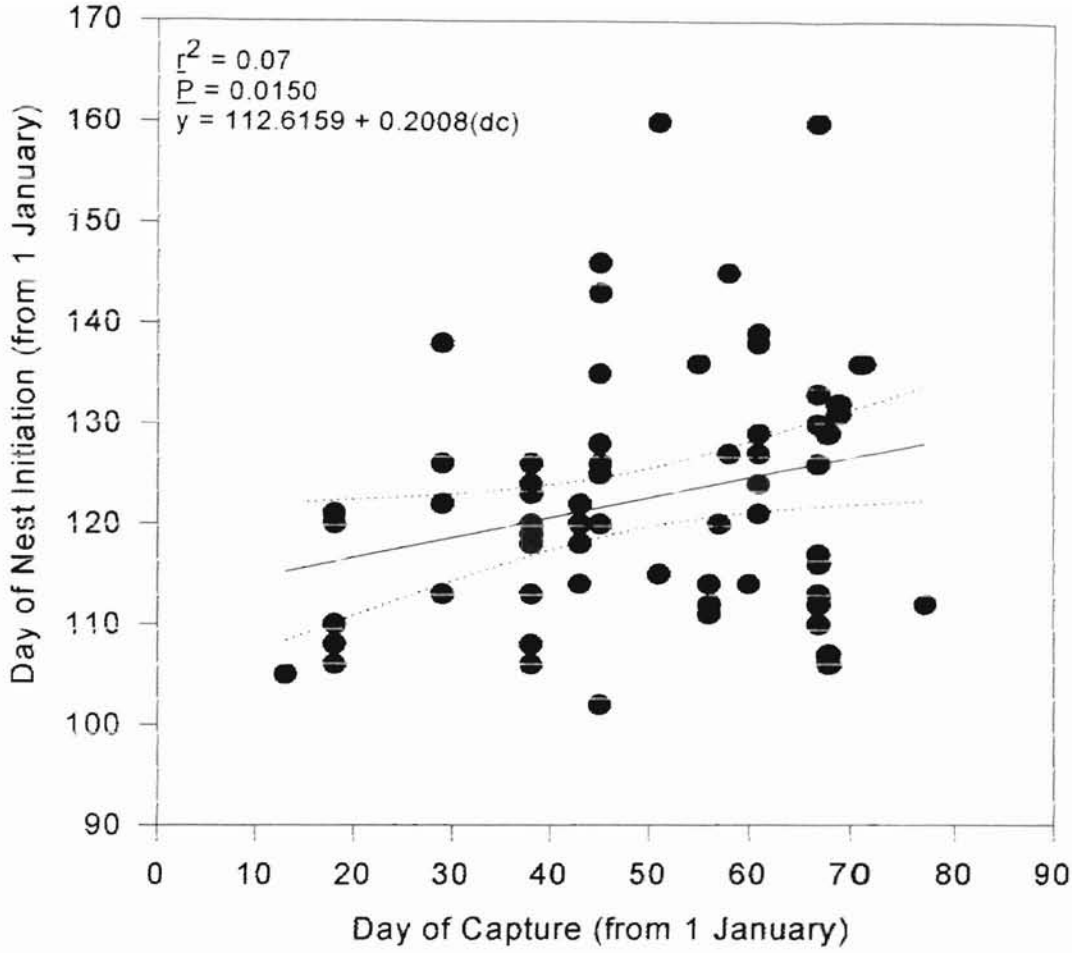

Figure 8. Relationship between date of capture (dc) and the date of first nest initiation (days from 1 January) for eastern wild turkey hens at Pushmataha Wildlife Management Area, Oklahoma, 1995-97. Values calculated using univariate linear regression model. Dotted lines designate the 95% confidence interval for the regression.

VITA

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Master of Science

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