AN ABSTRACT FOR THE THESIS OF

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Title: Wild turkey (*Meleagris gallopavo*) population growth in Kansas and the potential for regulation by enteric helminths

Abstract approved: ______________________

The present investigation focuses on the population dynamics of Kansas wild turkeys (*Meleagris gallopavo*) and one of the possible factors that could limit population growth in Kansas, enteric helminths. Analysis of Rural Mail Carrier Survey (RMCS) data suggested a seasonal index (summer) suitable for tracking wild turkey populations in Kansas. Exponential expansion of the wild turkey population in Kansas was observed in all regions of the state, with the exception of the southwestern region. An explanation of the observed wild turkey growth and suggestions for changes in the current management practices used by the Kansas Department of Wildlife and Parks (KDWP) for wild turkeys are provided. The study includes a survey of the enteric helminths of 72 wild turkeys collected in eastern Kansas. Seasonal comparisons of helminth prevalence between a spring (April to May 2001) and fall/winter (October to January 2001/2002) sample revealed higher helminth prevalence and species richness in the spring sample. A sub-sample (35) of the wild turkeys used for the helminth survey was analyzed and parasite abundances were correlated with principle component axes of measured epigamic characters of each bird. Analysis revealed no significant correlations between epigamic character expression and mean enteric helminth abundances, which suggests that helminth parasites are not affecting the vigor of individuals. The analysis did reveal two

principle components, one correlated with characters associated with body size and one correlated with snood length and skullcap width. Thus, snood length and skullcap width, which varied independently of age and have been demonstrated to be mate selection criteria for female turkeys, have the potential for indicating heritable resistance independent of age and vigor.

WILD TURKEY (*MELEAGRIS GALLOPAVO*) POPULATION GROWTH IN KANSAS AND THE POTENTIAL FOR REGULATION BY ENTERIC HELMINTHS

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Master of Science

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Approved by the Dean of Graduate Studies and Research

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PREFACE

The thesis contains 5 chapters. The first chapter is an introduction to the research conducted, and the final chapter is a general summary of the work. Chapters 2, 3, and 4 were written in the style of the journal to which they were submitted. Chapter 2 was written in the style of Ecological Applications, chapter 3 was written in the style of the Journal of Parasitology, and chapter 4 was written in the style of the Southwestern Naturalist.

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CHAPTER ONE
INTRODUCTION TO THESIS

The restoration of the wild turkey (*Meleagris gallopavo*) in North America is considered one of the greatest success stories in the history of wildlife management. Logging, deforestation, and land management practices almost drove the wild turkey to extinction (Kennamer et al., 1992) by the early 1930's, with numbers estimated as low as 100,000+ birds in the continental United States (Healy and Powell, 1999). Restoration efforts began in the 1940's, but failed, primarily because released domestic turkeys lacked the ability to avoid predators and forage in the wild. Trap and transplant efforts began in the late 1940's. These trap and transplant efforts utilized drop nets and pole traps to capture wild turkeys that subsequently were transported into areas devoid of wild turkeys (Kennamer et al., 1992). The invention of the cannon net greatly increased the efficiency of trap and transplant efforts and has played a key role in the resurgence of the wild turkey. Wild turkey populations in the United States currently are estimated at over 5,000,000 birds with a range encompassing all lower 48 states, and even Hawaii. With ever-increasing wild turkey populations comes the task of managing these populations for overall health and sustainable harvest. Recent research has focused primarily on wild turkey survival reproduction, nesting success, and habitat requirements in an attempt to better understand the factors limiting populations of wild turkeys (Hennen 1999; Spears, 2002; Wright and Vangilder, 2001).

The history of the wild turkey in Kansas mirrors its history across the United States, with wild turkeys being extirpated from most of their native range by the early 1900's (Hlavachick and Blair, 1997). Several Rio Grande turkeys (*M. g. intermedia*) crossed the southern border of Kansas from Oklahoma and founded an isolated population along the

Arkansas River, and prompted the Kansas Forestry Fish and Game Commission to hire a "turkey study leader" in 1962 (Hlavachick and Blair, 1997). Re-introduction efforts in Kansas began with 125 Rio Grande turkeys from Texas being released at several locations across the southern part of the state. Trap and transplant efforts continue in Kansas, however most of the birds presently being trapped in Kansas are transplanted into other states to assist with their wild turkey restoration efforts. Wild turkey populations in Kansas gradually increased back to huntable numbers with a spring hunting season initiated in 1974 and a fall hunting season initiated in 1979 (Hlavachick and Blair, 1997). Beginning with the first spring season, the Kansas Department of Wildlife and Parks (KDWP) has initiated hunter harvest surveys to track the growth and harvest of the turkey population in Kansas. Wild turkeys were added to the Kansas Rural Mail Carrier Survey (RMCS) in 1986 in an attempt to provide further information about their population dynamics in Kansas (Applegate, 1997).

Recent research efforts of the KDWP primarily have focused on two areas, the first being an analysis of RMCS data for wild turkeys. The present research includes an analysis of fourteen years of RMCS data and fourteen years of corresponding hunter harvest data. The analysis includes the determination of a seasonal index suitable for tracking populations of wild turkeys in Kansas, as well as an investigation of the overall utility of the indices generated from the RMCS and an examination of the current growth patterns exhibited by wild turkey populations across the state. Chapter two also includes an explanation of the observed wild turkey growth and suggestions for changes in the current management practices used by the KDWP for wild turkeys. The RMCS has the potential to assist the KDWP in setting harvest limits, season duration, and hunting zones to maintain a viable wild turkey population that will allow for a sustainable harvest for future generations.

The second focus of recent KDWP research has been on the parasites of wild turkeys. Mock et al. (2001) cataloged the ectoparasites of wild turkeys in Kansas and the present study catalogs their enteric helminths. Chapters three and four describe the enteric helminths based on a survey of 72 wild turkeys harvested in southeastern Kansas from April 2001 to February 2002 and the possible role they play in population regulation. Looking at a sub-sample (35) of the 72 wild turkeys used in the parasite survey, the Hamilton-Zuk (1982) hypothesis was used to determine the effects of enteric helminths on populations of wild turkeys in Kansas.

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CHAPTER TWO
THE KANSAS RURAL MAIL CARRIER SURVEY (RMCS): THEORETICAL CONSIDERATIONS AND MANAGEMENT IMPLICATIONS FOR THE WILD TURKEY (*MELEAGRIS GALLOPAVO*)

Abstract. Rural mail carrier surveys (RMCS) have been used to track populations of game animals in the United States for many years, but few states employ RMCS data to track populations of wild turkeys (*Meleagris gallopavo).* Fourteen years of RMCS data and fourteen years of corresponding hunter harvest data were analyzed for trends in wild turkey population dynamics in Kansas. Exponential growth by expansion was seen in all regions of the state with the exception of the southwest, where a zero growth model provided a better fit. Correlations of the residuals from respective exponential models among adjacent regions of the RMCS suggest that the RMCS is internally consistent. Comparison of indices derived from the RMCS and hunter harvest survey data indicated a Type-I functional response curve in the fall hunting season and a Type-II functional response curve in the spring hunting season. Changes in current management strategies are proposed to increase harvest to correspond with the observed growth trend seen in turkey populations in Kansas.

Key words: wild turkey, *Meleagris gallopavo*, Rural Mail Carrier Surveys, Kansas, population establishment, expansion, population dynamics.

INTRODUCTION

Rural Mail Carrier Surveys (RMCS) have been used for over forty years to investigate long-term trends in the population dynamics of many game animals (Greeley et al. 1962, Labisky 1975, Warner 1981), and have been used in Kansas since the 1960's with wild turkeys (*Meleagris gallopavo*) being added to the Kansas RMCS in 1986 (Applegate 1997). Over 400 rural mail carriers, while driving more than 200,000 miles of Kansas roads, record observations of wild turkeys each year (Applegate, 1997). Although population indices generated from RMCS data might not be sensitive enough to demonstrate minor fluctuations in game populations, RMCS data can be useful in tracking long-term trends, thereby allowing managers to make informed management decisions regarding season lengths, hunting zones, and harvest limits.

From a theoretical standpoint, the RMCS has the potential to produce a meaningful relative index of a species' abundance. The number of individuals of a given species encountered by a predator moving through a landscape will be directly proportional to that species' density when the distribution of individuals approaches randomness (Holling 1959). Encounter rate also is determined by species detectability and modified by capture efficiency. Sightings by predators (rural mail carriers) constitute captures with virtually no handling time, which results in a linear relationship (Type-I functional response) (Holling 1959, Real 1977, 1979) between density and individuals observed. Thus, assuming detectability varies randomly and independently among rural mail carriers, RMCS indices should be useful metrics of relative abundance across a wide range of wild turkey densities.

Wild turkeys are gregarious birds that, in late fall, aggregate in large flocks that persist throughout the winter (Healy 1992a). During the spring breeding season and the summer brood-rearing season, wild turkeys disperse according to social status (Buford et al. 1994) thereby giving rise to distributions that are conducive to representative RMCS relative indices. Of these two seasons, summer RMCS data should be the most useful for tracking wild turkey population dynamics because during the spring season, males have a home range that they display in and defend from other males (Healy 1992a), which might lead to an overestimation of wild turkey relative abundances based on visual observations. Moreover, seasonal shifts in the diet of wild turkeys will have an effect on the distribution of wild turkeys during a particular season. As the diet of the wild turkey shifts from insects and vegetation in the summer to primarily mast crops and other vegetation in the fall (Hurst 1992), wild turkeys are more likely to be seen foraging in crop fields and woodlots, again creating the potential for a biased estimate. Thus, in the summer, wild turkeys are more broadly dispersed, and their distributions less predictable, indicating that the summer data should produce the most robust metric of their population dynamics.

The present investigation examines 14 years of summer RMCS data and 14 years of corresponding hunter harvest data for wild turkeys in Kansas, collected by rural mail carriers and personnel from the Kansas Department of Wildlife and Parks (KDWP). The goals of my investigation are to evaluate the utility of the RMCS for monitoring the large-scale population dynamics of wild turkeys in Kansas and to examine these trends as a means of addressing current management practices for wild turkey in Kansas.

METHODS

The Kansas RMCS is conducted annually in the winter (3rd or 4th week of January), spring (3rd week of April), summer (3rd week of July), and fall (2nd week of October) (Applegate, 1997), and the data are pooled into six regions; southwest, southcentral, southeast, northwest, northcentral, and northeast (Fig. 2.1). Mail carriers report the number of wild turkeys seen and the total distance driven over a five-day period (Applegate and Williams 1995). Collection of the RMCS data as the number of wild turkeys observed/route precluded an analysis of wild turkey dispersion. The flocking and reproductive behaviors of the wild turkey indicate that the distribution of wild turkeys would be the least aggregated during the summer. Thus, RMCS relative indices were calculated for each region by standardizing the number of wild turkeys observed during the summer observation period by the number of kilometers driven. A statewide summer index also was calculated by pooling the regional RMCS data.

Annual summer indices were smoothed by using the following basic algorithm (Gauch 1982):

$$N_t = [N_{t-1} + 2N_t + N_{t+1}] / 4$$

An exponential growth model was fit to the smoothed summer RMCS indices within each region by iterative determination of intrinsic rates of increase, and the residuals examined by using mean-square successive difference tests (von Nuemann et al. 1941). Relationships between the residuals from the exponential model and climate data (annual precipitation, seasonal precipitation, and mean seasonal temperature) were examined by using Pearson's product-moment correlation analysis (Zar 1996). Climate data were obtained from the National Oceanic & Atmospheric Administration's (NOAA) National

Climatic Data Center (NCDC) for weather stations located centrally within each region of the RMCS. All statistical analyses were performed by using SAS 8.2 (SAS Institute Inc., Cary, NC), with a type I error rate of 0.05.

RESULTS

An exponential growth model provided a good fit (X^2 ranging from 0.212 to 2.505, d.f. = 13, $P > 0.95$) to wild turkey population growth in every region of Kansas, with the exception of the southwest, where a zero growth model ($X^2 = 0.181$, d.f. = 13, $P > 0.95$) provided a better fit (Fig. 2.2). Statewide, wild turkey population growth did not deviate significantly from an exponential model ($X^2 = 0.089$, d.f. = 13, $P > 0.95$). Smoothed summer RMCS indices were correlated with the proportion of RMCS routes reporting turkeys for all regions (r_P ranging from 0.7799 to 0.9293; P ranging from 0.001 to 0.0001) (Fig. 2.3). Although, the deviations of the smoothed summer indices were serially correlated within regions (C ranging from 0.464 to 0.875, d.f. = 13, P ranging from < 0.0005 to 0.025), deviations of the raw summer indices from exponential models were not serially correlated for any region (C ranging from 0.218 to 0.319, d.f. = 13, $P > 0.10$) except the southcentral ($C = 0.634$, d.f. = 13, $P < 0.0025$). Residuals from the exponential growth models were correlated between the southwest and northwest regions, among the southcentral, southeast, and northeast regions, and between the northeast and northcentral regions (Table 2.1). Mean winter precipitation (November to February) was positively correlated with smoothed residuals in the three northern regions of the state (NC: $r_P = 0.8156$, $P = 0.004$; NE: $r_P = 0.5687$, $P = 0.034$; NW: $r_P = 0.848$, $P = 0.001$). Correlation analysis revealed no significant correlations between any climate data and the residuals in the three southern regions of the state.

Although, a comparison of fall daily harvest data with the statewide smoothed RMCS index is suggestive of a Type-I functional response curve (Fig. 2.4), the spring harvest data approximate a Type-II functional response (Fig. 2.5). Pooling the spring and fall seasons also produced an approximation of a Type-II functional response curve (Fig. 2.6).

Fig. 2.1. The six regions of the Kansas Rural Mail Carrier Survey.

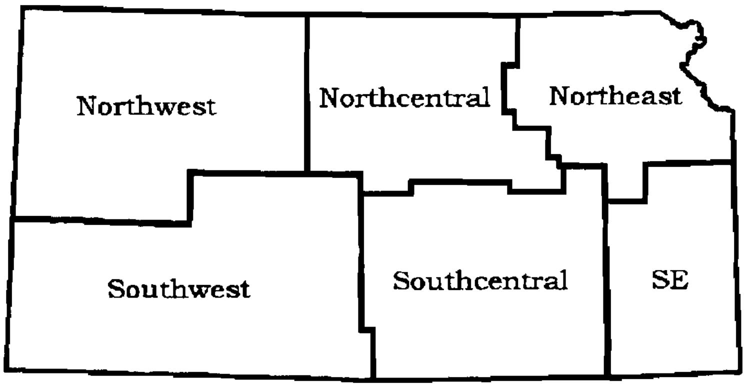

Northwest
Northcentral
Northeast
Southwest
Southcentral
SE

Fig. 2.2. Smoothed summer RMCS indices by region (1987 to 2000) and the corresponding growth rates (r): (A) Northcentral, (B) Northeast, (C) Northwest, (D) Southcentral, (E) Southeast, and (F) Southwest.

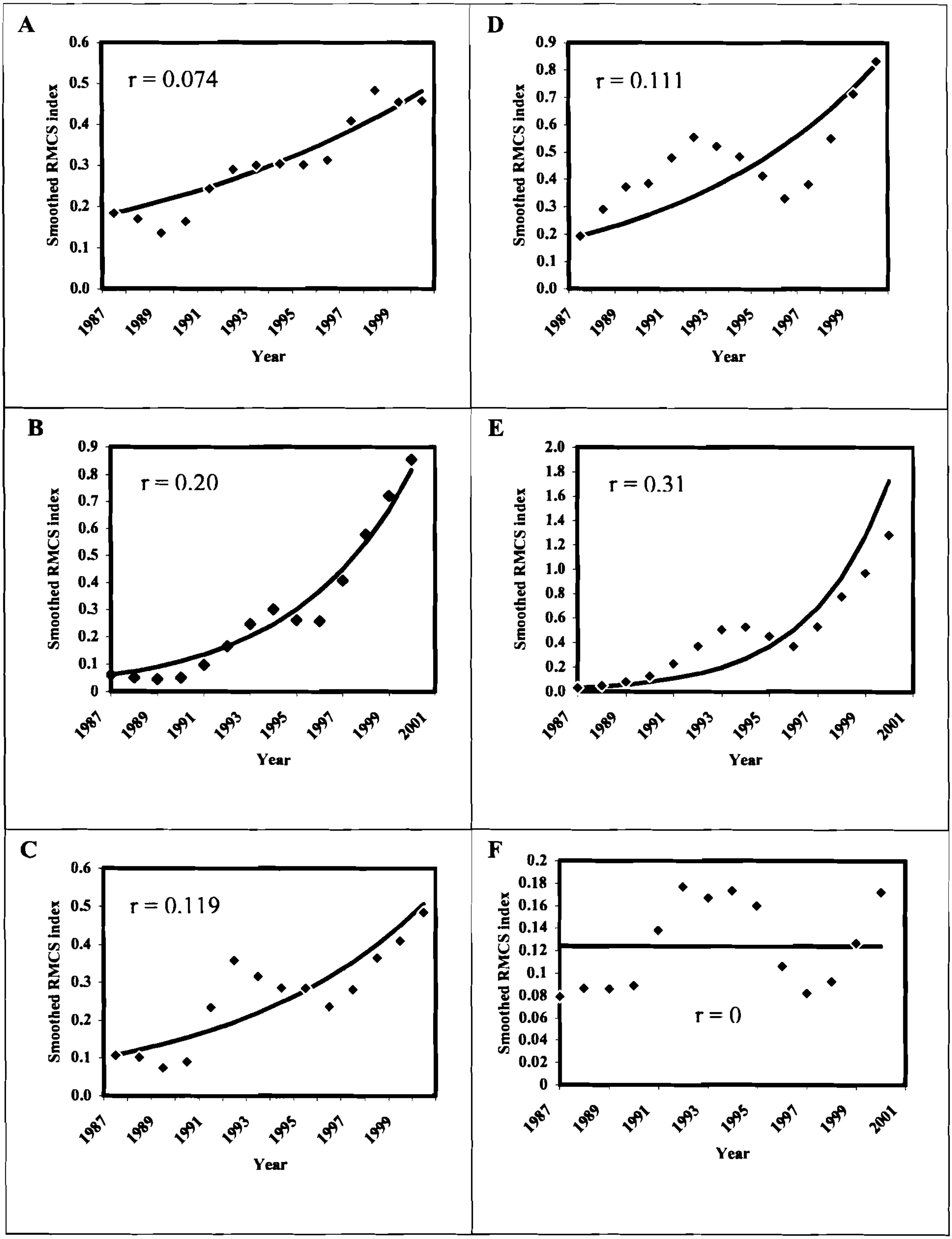

A
r = 0.074
Smoothed RMCS index
Year
D
r = 0.111
Smoothed RMCS index
Year
B
r = 0.20
Smoothed RMCS index
Year
E
r = 0.31
Smoothed RMCS index
Year
C
r = 0.119
Smoothed RMCS index
Year
F
r = 0
Smoothed RMCS index
Year

Fig. 2.3. Smoothed RMCS indices as a function of the proportion of RMCS routes reporting wild turkeys

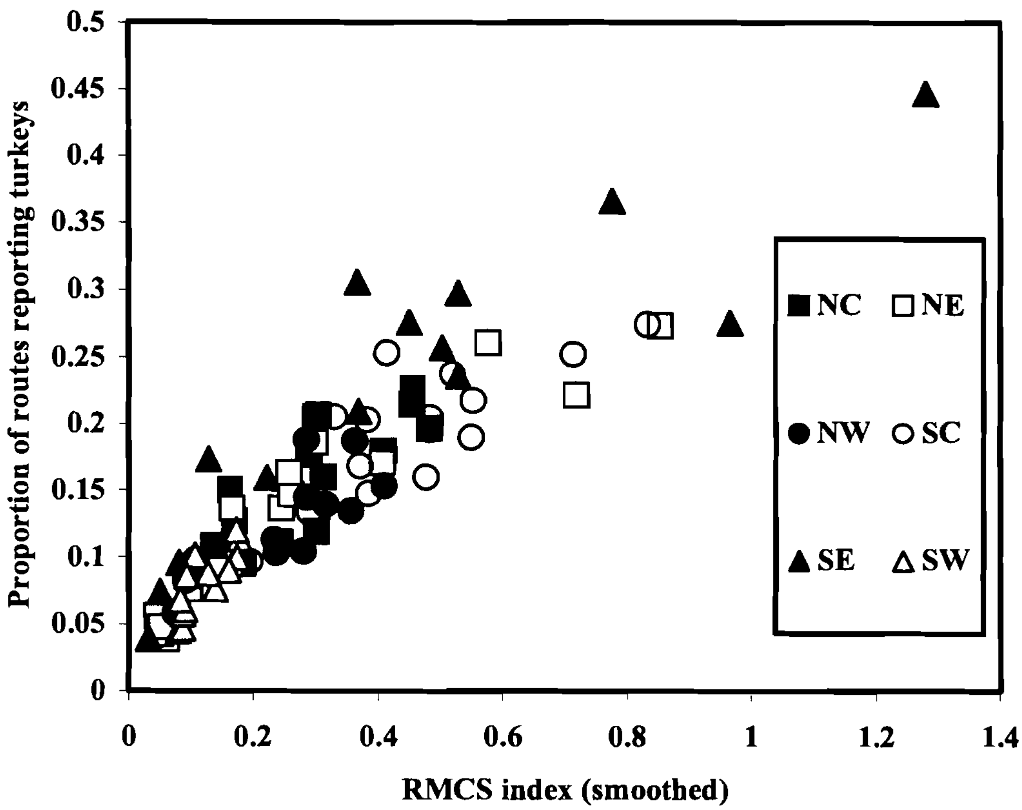

Proportion of routes reporting turkeys
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
RMCS index (smoothed)
NC
NE
NW
SC
SE
SW

Table 2.1. Pearson's product-moment correlation coefficients and associated probabilities for the residuals of smoothed summer indices among the six geographical regions of the Kansas RMCS.

	Northcentral	Northeast	Northwest	Southcentral	Southeast
Northeast	0.5692 P = 0.034				
Northwest	0.3884 P = 0.170	0.4099 P = 0.145			
Southcentral	-0.1815 P = 0.535	0.2384 P = 0.412	0.6656 P = 0.009		
Southeast	-0.0064 P = 0.983	-0.0153 P = 0.959	0.6543 P = 0.011	0.5800 P = 0.029	
Southwest	0.1686 P = 0.564	0.4835 P = 0.080	0.7099 P = 0.004	0.3753 P = 0.186	0.2810 P = 0.330

Fig. 2.4. Total Kansas fall harvest as a function of the statewide smoothed summer index.

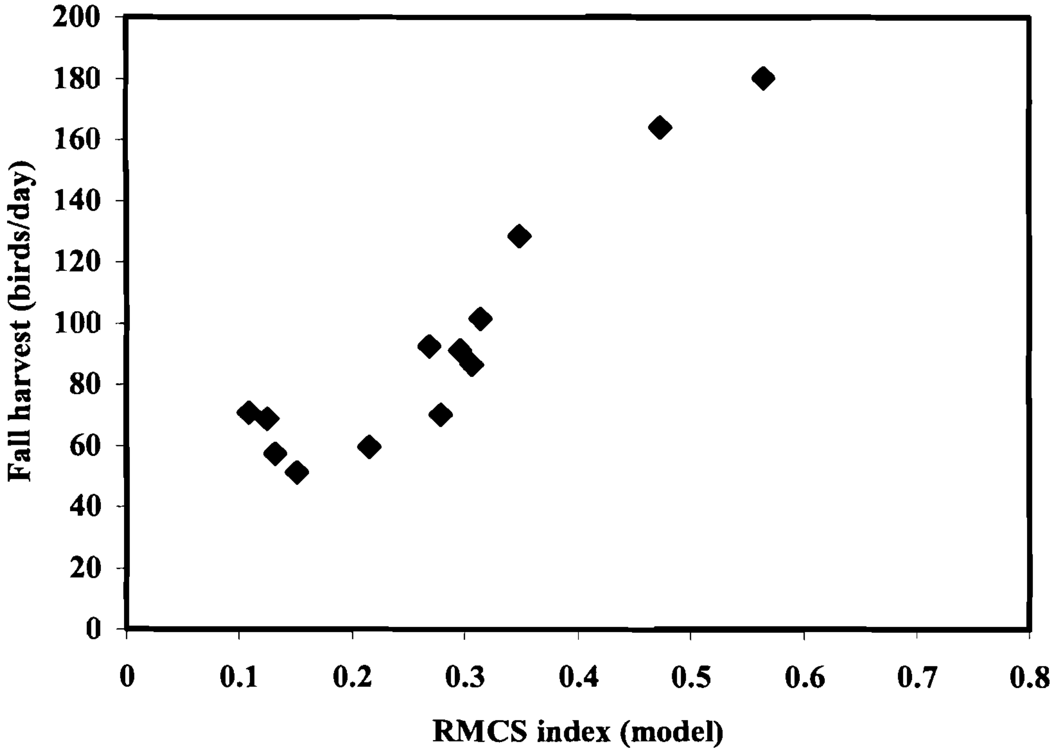

200
180
160
140
120
100
80
60
40
20
0
Fall harvest (birds/day)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
RMCS index (model)

Fig. 2.5. Total Kansas spring harvest as a function of the statewide smoothed summer index.

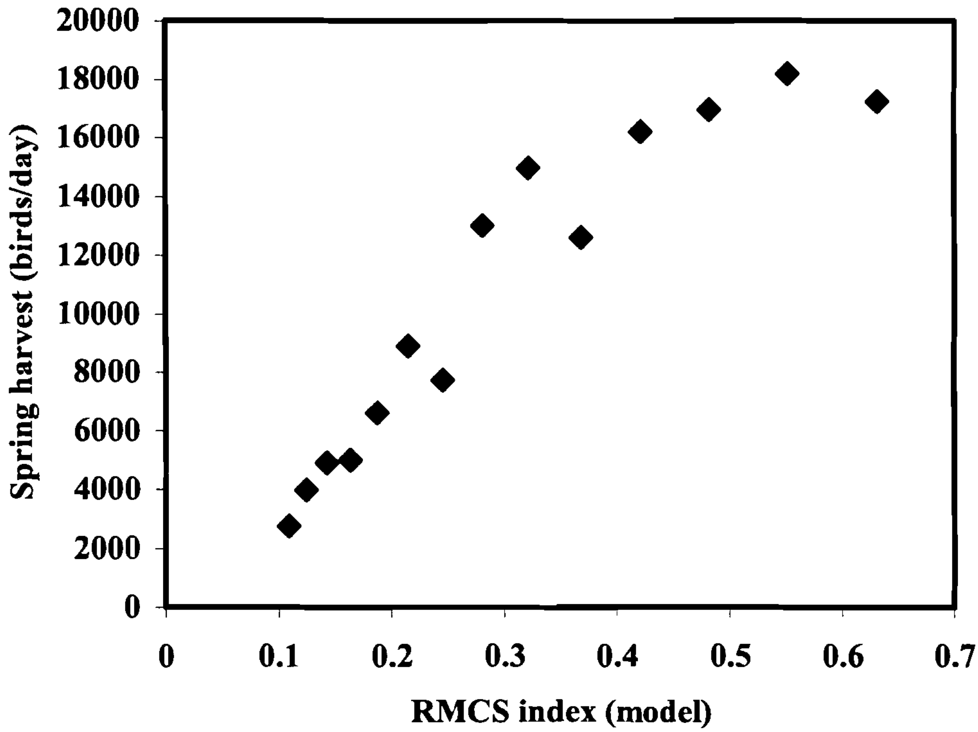
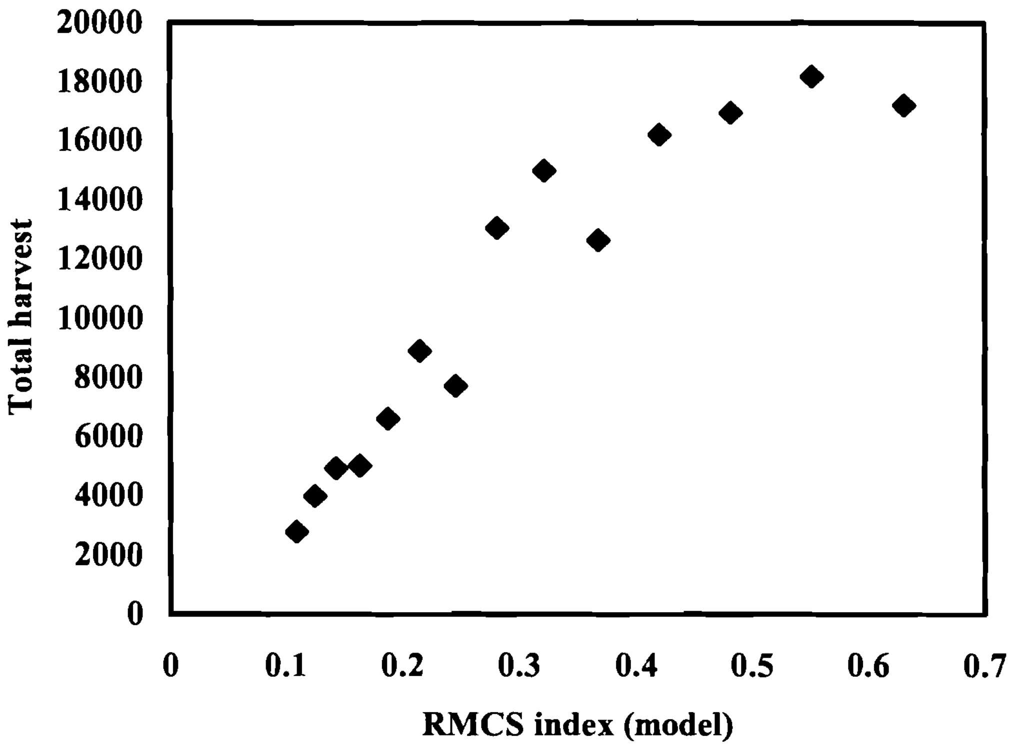
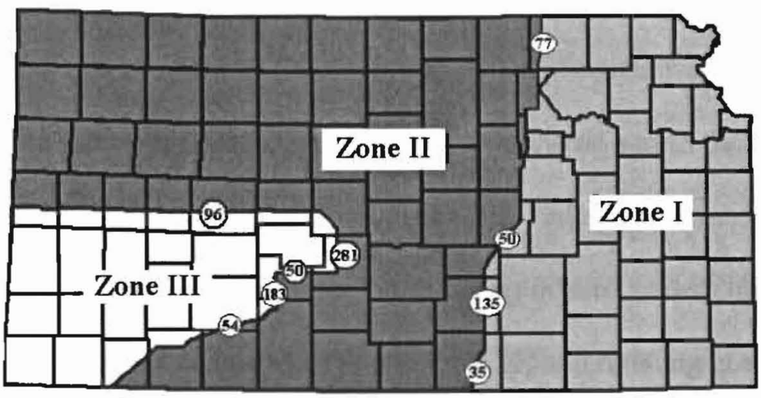

20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Spring harvest (birds/day)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
RMCS index (model)

Fig. 2.6. Total combined Kansas harvest (fall and spring) as a function of the statewide smoothed summer index (1987 to 2000).



20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Total harvest
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
RMCS index (model)

Fig. 2.7. Proposed new spring and fall hunting zones for Kansas based on magnitude of expansion rates and the combination of RMCS zones with asynchronous fluctuations.


Zone II
Zone I
Zone III
77
96
50
281
50
183
135
54
35

DISCUSSION

Analysis of RMCS relative summer indices indicated exponential growth of the wild turkey population in all areas of the state with the exception of the southwest. Correlations between smoothed RMCS indices and the proportions of routes reporting turkeys (Fig. 3) indicate that observed growth trends are the result of the spread and establishment of new populations, rather than the exponential growth of existing populations. A primary factor that can limit the spread and establishment of wild turkey populations is roost tree availability (Healy 1992b). The frequency of riparian areas containing suitable roost trees declines as you move westward across the state. Accordingly, observed population growth rates for wild turkeys are higher in the eastern regions of the state and decline in the west, culminating in zero growth in the southwest. Spears (2002) indicated that factors such as available ground roosting cover for poults, which might be reduced by intensive cattle grazing, also could be limiting wild turkey populations in the southwest region. Possibly, available roosting cover for both poults and adult wild turkeys might account for the low growth rates observed in this region, although the determination of such limiting factors was outside the scope of the present investigation.

Even though the expansion of Kansas wild turkey populations is exponential in nature, there still are non-random fluctuations that suggest individual wild turkey populations experience high and low-growth years. Annual fluctuations in wild turkey population size often are directly related to nest success (Healy and Powell 1999). In dry years, plant growth is reduced and thus available nesting cover and forage is reduced for hens and their poults (Healy and Powell 1999). Correlations between mean winter precipitation and RMCS residuals from exponential growth in the northern regions of Kansas support the contention that the fluctuations around the exponential trend represent year-to-year within-population variability. Moreover, correlations among the residuals from adjacent regions are a prediction of Moran's theorem (1953), which states the abundance of one population is proportional to the abundance of another population, if stochastic environmental effects experienced by the two populations are proportional. Correlations among spatially correlated regions are consistent with Moran's theorem and imply internal consistency of the RMCS data. If a link between winter precipitation and nest success can be established in the northern regions, a similar causative factor might be established in the southern regions, providing a powerful management tool for predicting year to year fluctuations in wild turkey populations. Hennen (1999), concluded that the critical factor limiting recruitment of wild turkey populations in southcentral Kansas was the amount and timing of spring/summer precipitation and that poult survival was related to the number of rainfall events over 2.54 cm. Therefore a link between precipitation data and population fluctuations in the southern regions in Kansas might well exist, but the regional analyses utilized in the present study were not able to detect this link.

Although the suggestion that roost tree availability limits the expansion of wild turkey populations precludes a dramatic overshoot of carrying capacity for wild turkeys in Kansas, high densities pose other risks for this and other game species. The large turkey population in the state of Kansas already is a pressing concern for many landowners (Applegate *pers. comm.*). Therefore, if wildlife acceptance capacities (Decker and Purdy 1988) for wild turkeys in certain regions have been exceeded, harvest limits for hunters need to be increased in these areas to lower wild turkey densities to acceptable levels. Hunting or human caused mortality is a significant cause of mortality of adult wild turkeys (Wright and Vangilder 2001, Healy and Powell 1999), and the natural predators of adult wild turkeys, such as coyotes (*Canis latrans*) and bobcats (*Lynx rufus*) (Miller and Leopold 1992) presently are not regulating the Kansas turkey population, presumably due to saturation with available prey items. Thus, the ability to manage wild turkey densities depends on the potential for wild turkey hunters to regulate the wild turkey population.

The Type-II functional response curve indicated by the spring harvest data suggests spring hunting no longer is a viable means of controlling wild turkey populations. The stable hunter success rate in the spring hunting season and the exponential growth of tags sold (data not shown) suggests that spring hunters are limited by the number of tags available to each hunter. The Type-I functional response curve suggested by the fall harvest data likely is the result of the low numbers of hunters pursuing wild turkeys during the fall hunting season (data not shown), as well as lower hunter success in the fall hunting season. The low fall hunter participation and success rate suggests that even promoting a relatively high fall harvest, as per the present management strategies employed by the KDWP (liberal bag limit of four wild turkeys in the eastern regions of the state), might not substantially affect the Kansas wild turkey population. In order for hunters to have the potential to regulate the wild turkey population in Kansas, spring bag limit increases need to be considered in areas experiencing problems associated with high wild turkey densities.

RMCS zones with similar rates of expansion and asynchronous population growth residuals were combined to propose new management zones (Fig. 2.7) that allow for management based on growth rates and facilitate rescue-effects when a portion of the zone suffers heavy harvest or a poor recruitment year. Other proposed changes in current management practices include a one-bird increase per hunter in regions of the state where the wildlife acceptance capacity for wild turkeys has been reached or surpassed. The management strategy of harvesting hen wild turkeys in the spring also might have to be considered by KDWP personnel. The likelihood of the public accepting such a harvest strategy is highly unlikely, but the current harvest strategy, which allows only the harvesting of males in the spring after they have bred hens, likely will have little impact on wild turkey population growth.

In summary, the Kansas RMCS was able to detect the exponential trend of expansion of Kansas wild turkey populations, and year-to-year fluctuations within these populations. There exists no population estimation for comparison, but correlated fluctuations among adjacent zones suggest internal consistency of the RMCS. The data also facilitate creation of management zones with similar expansion rates and asynchronous population dynamics, which can temper the combined effects of hunting and poor recruitment years via recolonization.

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CHAPTER THREE
UTILIZING THE HAMILTON-ZUK HYPOTHESIS AS A METRIC OF THE LONG-TERM EFFECTS OF ENTERIC HELMINTHS ON POPULATIONS OF WILD TURKEYS (*MELEAGRIS GALLOPAVO*)

ABSTRACT: Costs associated with the production of epigamic characters might make them honest indicators of a male's fitness. The Hamilton-Zuk hypothesis suggests epigamic characters might be indicators of a male's heritable resistance to parasites, predicting a negative correlation between parasite abundance and the elaboration of epigamic characters, within a species or subspecies. Principal component analysis (PCA) of the epigamic characters of 35 male wild turkeys from a zone of Rio Grande (*Meleagris gallopavo intermedia*) and eastern (*M. g. silvestris*) hybridization revealed variation in characters that covaried with body size (beard length and spur size) and characters that varied independently of body size (snood length and skullcap width), the latter of which have the potential for indicating heritable resistance. None of the PCA axes were correlated with mean enteric helminth abundances, which suggests that helminth parasites are not affecting the vigor of wild turkeys in southeastern Kansas, and apparently have not exerted selective pressure in the past to advertise resistance.

Darwin (1859) first suggested that female choice might be responsible for the production of extravagant plumage, ornamentation, and weaponry by males. Fisher's (1930) runaway-selection model suggests that this selective pressure eventually will lead to extreme elaborations of male epigamic characters that handicap the males possessing them. Kodric-Brown and Brown (1984) tempered the ideas of Fisher (1930) by suggesting that costs associated with the production of epigamic characters would make them honest indicators of male fitness. Hamilton and Zuk (1982) proposed that epigamic characters indicate a male's heritable resistance to parasites, which, although predating Kodric-Brown and Brown (1984), essentially is a restricted view of their model. Thus, within a species or sub-species, one would expect to see a negative correlation between epigamic characters and parasite abundance (Hamilton and Zuk, 1982). Interspecifically, a positive correlation between epigamic characters and parasite richness and/or abundance is expected, because of stronger selective pressure to advertise parasite resistance (Hamilton and Zuk, 1982).

The predictions of the Hamilton-Zuk hypothesis have been both supported (Hillgarth, 1990a&b, Clayton, 1990, Zuk et al., 1990) and refuted (Lopez, 1999, Garvin and Remsen, 1997) by empirical work in various systems. These mixed results suggest that in many cases factors other than parasitism act as determinants of vigor and, ultimately, fitness. The predictions of the Hamilton-Zuk hypothesis only will hold true in systems in which parasites are affecting host vigor and/or reproductive potential and where selection for resistance is weakened by factors such as the coadaptive balanced polymorphism described by Hamilton and Zuk (1982). Notably, selection for resistance also can be weakened by the aggregated distribution of most parasites, which can arise through several ecological processes unrelated to heritable resistance (Crofton, 1971). In the context of the Hamilton-Zuk hypothesis, females might be selecting healthy males, who are not necessarily resistant, but simply have not been exposed, thereby weakening selection for resistance. The utility of the Hamilton-Zuk hypothesis is that it allows for the detection of the potential effects of parasites on host populations. Restricting application of the Hamilton-Zuk hypothesis to examinations of the main assumption that parasites are having, and have had in the past, a substantial effect on host fitness, facilitates evaluation of the effects of parasites on a host population. If parasites are having an effect on epigamic character expression, and thus sexual selection, then it must be inferred that they are affecting vigor and, ultimately, the dynamics of host populations.

Wild turkeys (*Meleagris gallopavo*) are a good model system for such an application of the Hamilton-Zuk hypothesis. Wild turkeys are host to numerous enteric helminths (Davidson and Wentworth, 1992), and are highly polygynous with males frequently engaging in combat to establish dominance (Healy, 1992), and associating with females only for breeding (Buchholz, 1995). Male wild turkeys also possess a suite of distinctive, quantifiable epigamic characters, e.g., protruding beard, tibiotarsal spur, snood, and skullcap. Moreover, Buchholz (1995) found that female selection does occur based on epigamic characters, particularly snood length and skullcap width, and that male-male combat victors could be predicted by quantifying snood length. The fact that Buchholz (1995) found a negative correlation between total coccidian intensity and stretched snood length also suggests that the Hamilton-Zuk hypothesis can be applied to this system.

The purpose of the present investigation is to use the Hamilton-Zuk hypothesis to determine whether enteric helminths are affecting a wild turkey population in southeastern Kansas. Negative correlations between epigamic character expression and parasite abundance would suggest that parasites are having a negative effect on host populations. Given the aggregated distribution of parasites and the relatively benign impact of enteric helminths, it is predicted that parasites do not limit wild turkey populations.

MATERIALS AND METHODS

Forty-six turkeys from a zone of Rio Grande and Eastern hybridization (*M. g. intermedia X M. g. silvestris*) were obtained from southeastern Kansas, during the Kansas Governor's One-Shot Turkey Hunt (Butler County: 11 April 2001 to 13 April 2001). Of these 46 turkeys, 35 were used (Fig. 3.1) in an attempt to minimize spatial variation of the sample. Snood lengths were measured after suspending a 30g weight from the snood (Buchholz 1995). Beard length was measured from the calamus to the distal end of the beard. Spur length (linear distance) and spur diameter were measured by using a Vernier caliper. Skullcap width was measured by using a flexible ruler at a point directly above the eyes. All length measurements were made in millimeters. Body mass was measured on a certified digital scale.

Wild turkey viscera were removed, placed in plastic sample bags, covered with boiling water, and agitated to relax the helminths. A quantity of formalin then was added to produce a concentration of 5-10% to fix and subsequently preserve the parasites. Preserved intestines were opened with a longitudinal incision, and the contents washed through a series of stacked sieves with the smallest sieve being 150µm, as described by Kalla et al. (1997). The washings from each sieve were examined by using a stereo-microscope. Recovered parasites were fixed, stained, and identified by using conventional methods. Parasite identities were confirmed by comparison with museum specimens. Epigamic character data were subjected to principle component analysis (PCA), and using Pearson's product-moment correlation analysis, the principle components were compared to the mean enteric parasite abundance of each bird. Parasite data were subjected to local nonmetric multidimensional scaling (LNMDS) and the resulting indirect gradients also were compared to the principle components of the PCA. Type-I error rate for all analyses was set at 0.05. All analyses, with the exception of the LNMDS ordination analysis (DECODA software), were performed by using SAS, version 8.2 (SAS Institute Inc., Cary, NC).

RESULTS

Principal component analysis of the epigamic characters of 35 male wild turkeys generated a principal component (Fig. 3.2) that correlated with beard length ($r = 0.90$, d.f. = 33, $P < 0.001$), spur length (left and right: $r = 0.89$, d.f. = 33, $P < 0.001$), and spur diameter (left: $r = 0.78$, d.f. = 33, $P < 0.001$; right: $r = 0.81$, d.f. = 33, $P < 0.001$), all of which covaried with body mass (r ranging from 0.52 to 0.76; d.f. = 33; $P \leq 0.001$). The second principal component (Fig. 3.2) correlated with snood length ($r = 0.61$, d.f. = 33, $P \leq 0.001$) and skullcap width ($r = 0.72$, d.f. = 33, $P \leq 0.001$).

Six species of enteric helminths were found, including one nematode, one digenean trematode, and four cestodes. Mean abundances for each species are listed in Table 3.1. There were no significant correlations between the two principle components and the abundances of any of the parasite species. There also were no significant correlations between the indirect gradients produced by LNMDS and either of the principle components.

Fig. 3.1. Collection localities for the 35 wild turkeys included in the investigation.

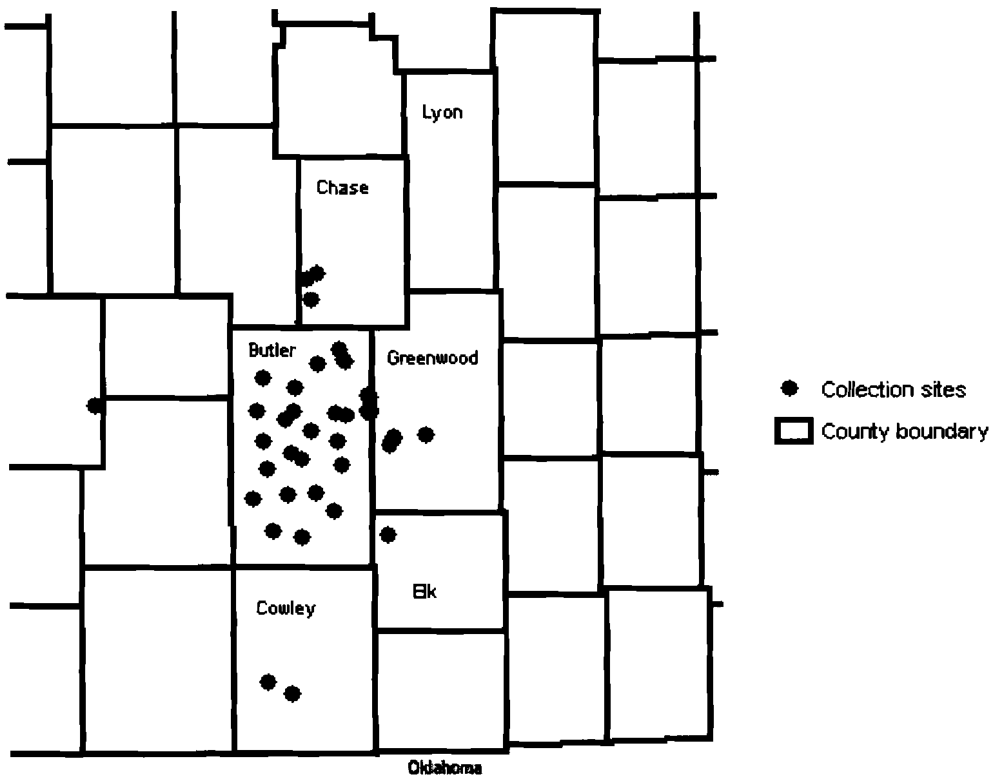
Lyon
Chase
Butler
Greenwood
Elk
Cowley
Oklahoma
Collection sites
County boundary

Fig. 3.2. Principle component analysis of epigamic characters of the 35 wild turkeys collected in southeastern Kansas.

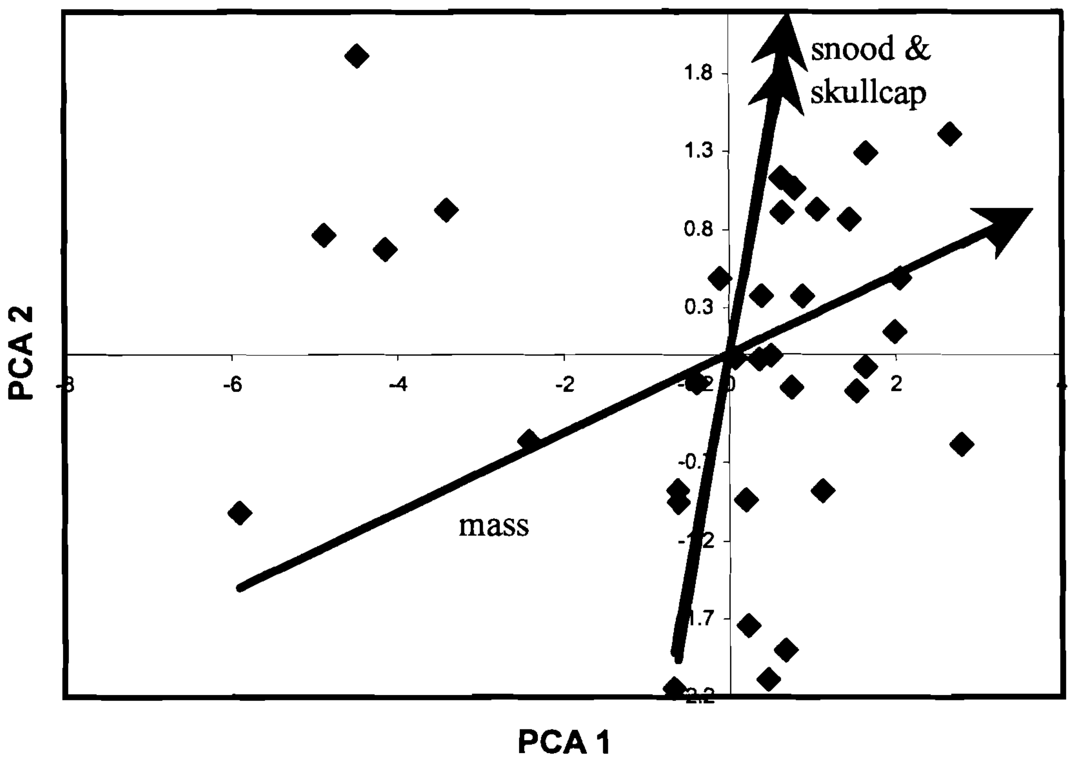
snood &
skullcap
mass
PCA 2
PCA 1
1.8
1.3
0.8
0.3
-6
-4
-2
2

Table 3.1. Mean abundance and range of enteric helminths collected from wild turkeys in southeast Kansas in April, 2001.

Parasite species	Mean abundance	Range
Heterakis gallinarum	0.46	0 – 9
Echinostoma revolutum	1.63	0 – 30
Metroliasthes lucida	32.11	0 – 136
Imparmargo baileyi	0.26	0 –8
Choanotaenia sp.	1.69	0 – 50
Raillietina sp.	0.06	0 – 1

DISCUSSION

In order for epigamic characters to act as honest indicators of potential fitness (Kodric-Brown and Brown, 1984), there should exist components that indicate an individual's general response to the proximal environment, as well as components that indicate a response to stochastic events such as disease. The principle component correlated with body mass and characters strongly associated with body mass (beard length, and spur size), can be considered to represent an individual's vigor. These characters are related to the overall health of the bird contingent upon its response to the environment, foraging ability, and age. This principle component was not correlated with any helminth abundance, which suggests that the helminth parasites at the intensities found, were not associated with morbidity. The first principle component also was not correlated with either LNMDS axis, which indicates no relationship between the structure of parasite communities and host vigor or, surprisingly, age and size. Typically, parasite community structure is related to host age (Bush, 1990) and body size or condition (Esch and Fernandez, 1993), but also can be related to season/year and gender (Bush, 1990). As the host gets older and larger, they are exposed to more infective stages of parasites through foraging or diet changes and therefore tend to have greater parasite species richness and/or abundances (Esch et al., 1990; Esch and Fernandez, 1993).

For a host individual, colonization by a parasite or pathogen can occur as a random event on both spatial and temporal scales (Crofton, 1971). Thus, in order for epigamic characters to indicate heritable resistance to disease they must have the potential to change in response to stochastic events that could occur after characters associated with vigor or age have been elaborated. Previous research supporting the

Hamilton-Zuk hypothesis (Hillgarth, 1990a&b, Clayton, 1990, Zuk et al., 1990) has focused on plastic characters, such as comb length (Zuk et al., 1990), and tail length (Zuk et al., 1990).

The second principle component for the epigamic characters correlated with snood length and skullcap width, demonstrated variation in these characters independent of those that represent vigor. These characters have the potential to respond to stochastic events as they are fleshy characters that are influenced by the immediate health of the bird (Buchholz, 1995). Saino et al. (1999) found that carotenoids are removed from blood plasma when birds are immunocompromised, and thus are not available for advertisement via epigamic characters, such as snood and skullcap. In wild turkeys, these two characters have the strongest influence on female mate choice (Buchholz, 1995), which suggests indicators of response to stochastic phenomena might be important in this system. Although previous research has shown these characters to covary with parasite infection (Buchholz, 1995), helminth abundances and LNMDS axes were not correlated with the second principle component, which suggests that enteric helminths and the structure of the helminth community are not affecting expression of these characters and have not exerted selective pressure to advertise heritable resistance to parasitic helminths in the past.

The Hamilton-Zuk hypothesis can be used to evaluate the effects of parasites in systems where there is selection by females for males (typically a polygynous mating system) that is weakened by factors such as balanced coadaptive polymorphisms, or ecological determinants of parasite aggregation. Moreover, hosts with characters that have the potential to indicate vigor as well as separate characters that have the potential to indicate a host's response to stochastic environmental factors allow for the use of the Hamilton-Zuk hypothesis to determine the nature of parasite effects on host populations. While most investigations have tested the Hamilton-Zuk hypothesis within a particular system, the real utility of the Hamilton-Zuk hypothesis lies in its potential for determining the effects parasites are having on a host population.

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CHAPTER FOUR
HELMINTHS OF WILD TURKEYS (*MELEAGRIS GALLOPAVO*) IN SOUTHEAST KANSAS

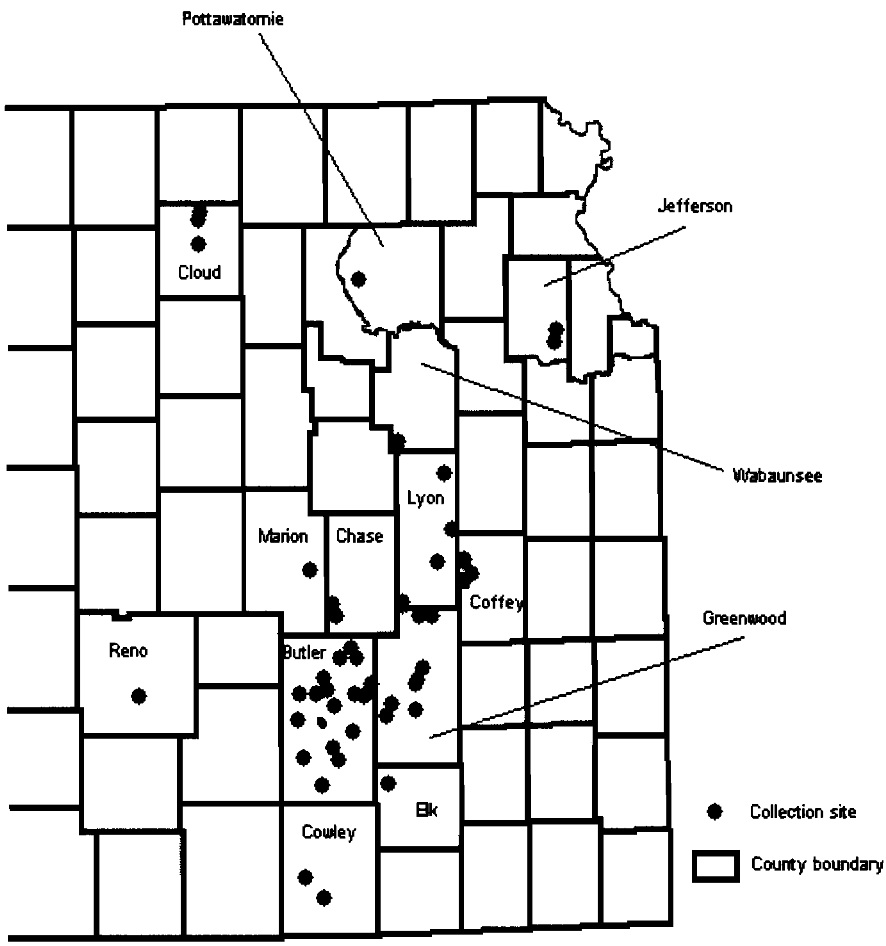
ABSTRACT - Viscera of 49 wild turkeys (*Meleagris gallopavo*) collected in the spring of 2001 and 23 wild turkeys collected in the fall/winter of 2001/2002, from 12 counties in southeastern Kansas were examined for enteric helminths. Examination revealed four cestode species, two trematode species, one nematode species, and one acanthocephalan species. Two cestode and two trematode species present in the spring sample also were present in the fall/winter sample. Parasite prevalence and mean intensities were similar for the four species found in both seasons. Parasite prevalence was similar to previous studies of enteric helminths of wild turkeys, with the exception of low richness and abundance of nematode species found in the present study.

The effects of parasites on populations of wild turkeys (*Meleagris gallopavo*) are poorly understood (Maxfield et al., 1963; Davidson and Wentworth, 1992). Many investigations of parasitism in wild turkeys have been undertaken (Williams, 1931; Kozicky, 1948; Gardinier and Wehr, 1949; Maxfield et al., 1963; Prestwood, 1968; Prestwood et al., 1973; Hon et al., 1975; Castle and Christensen, 1984), but these were restricted to the eastern region of the United States and, therefore, the eastern subspecies (*Meleagris gallopavo silvestris*). Wild turkey populations in Kansas consist of a few isolated populations of the eastern subspecies and the Rio Grande subspecies (*M. g. intermedia*) as well as numerous populations of hybrids (*M. g. silvestris* X *M. g. intermedia*). Wild turkeys are abundant in Kansas and their numbers continue to increase at an exponential rate (McJunkin and Zelmer, *unpubl. obser.*). The Kansas Department of Wildlife and Parks (KDWP) recently initiated investigations into the parasites of wild turkeys in Kansas because of a lack of baseline data. The first of these was a survey of the ectoparasites of wild turkeys in Kansas (Mock et al., 2001). The present investigation catalogs the enteric parasites of predominately hybrid wild turkeys in southeastern Kansas collected in the spring of 2001 and the fall/winter of 2001/2002.

METHODS - The spring sample consisted of forty-nine hybrid wild turkeys collected from April and May 2001 from several localities across the eastern half of Kansas (Fig. 4.1). A large portion of this sample (46 birds) came from the Kansas Governor's One-Shot Turkey Hunt (Butler County, Kansas: 11 April 2001 to 13 April 2001). The 23 birds comprising the fall sample were collected from October 2001 to February 2002. In total, 50 adult and 22 juvenile wild turkeys were examined, with the majority (69 of 72) of the birds being male. The spring sample consisted of all males, five of which were juveniles. The fall sample was comprised of three juvenile females and ten juvenile males, with the remainder being adult males. All birds were collected by the use of firearms.

Viscera were removed from recently killed wild turkeys, placed in plastic bags, covered with boiling water, and agitated to relax the helminths. A quantity of formalin then was added to produce a concentration of 5-10% to fix and preserve the parasites. Intestines were opened with a longitudinal incision, and the contents washed through a series of stacked sieves, with the final sieve being 150μm in size, as described by Kalla et al. (1997). The contents of each sieve were examined for helminths. Recovered parasites were fixed, stained, and identified by using conventional methods. All parasite identities were confirmed by comparison with museum specimens. Voucher specimens of all species have been deposited at the U.S. National Parasite Collection in Beltsville, Maryland (Table 4.1). Parasite prevalence (the percentage of hosts infected by a parasite species) and mean intensity (the average intensity level of a parasite species among infected hosts) were calculated as outlined by Bush et al. (1997).

Fig. 4.1. Location of host collection sites used in survey of Kansas wild turkey parasites.



Pottawatomie
Jefferson
Cloud
Wabaunsee
Lyon
Marion
Chase
Coffey
Greenwood
Reno
Butler
Elk
Cowley
Collection site
County boundary

RESULTS AND DISCUSSION - One acanthocephalan, two trematode, one nematode, and four cestode species were found in the spring wild turkey sample (Table 4.1). Of these species, only the two trematodes (*Echinoparyphium recurvatum* and *Echinostoma revolutum*) and two of the cestode species (*Metroliasthes lucida* and *Raillietina* sp.) were present in the fall/winter sample (Table 4.1). Ten birds were found to be free of parasitic infection. Geographic locations of host collection sites are shown in Fig. 4.1. Seasonal enteric helminth prevalence is shown in Table 4.1 and Fig. 4.2 with a seasonal comparison of enteric helminth mean intensities.

Trematodes - Two trematode species, *Echinoparyphium recurvatum* and *Echinostoma revolutum*, were found in wild turkeys in my survey. Both of these trematodes have been found previously in wild turkeys (Table 4.2). *Echinoparyphium recurvatum* was found in wild turkeys from Coffey and Lyon counties. *Echinoparyphium recurvatum,* a common parasite of waterfowl (Hon et al., 1975), is widely distributed (Evans, 1983) and has been found in wild turkeys in several states (Table 4.2), as well as ruffed grouse (*Bonasa umbellus*) in Michigan and Maine (Davidson et al., 1977) and ring-necked pheasant (*Phasianus colchicus*) in the panhandle of Texas (Pence et al., 1980). The life cycle of *E. recurvatum* includes snails as intermediate hosts (Yamaguti, 1958) and a wide variety of birds as definitive hosts (Evans, 1983). Infection for the definitive host occurs by ingestion of an infected snail. Wild turkeys are considered to be auxiliary hosts for this parasite (Hon et al., 1975). Prevalence and mean intensities of *E. recurvatum* were lower in the spring sample than in the fall/winter sample. This likely is due to prevalence levels of *E. recurvatum* being higher in Lyon, Greenwood, and Coffey counties, where the fall/winter sample was obtained, than in Butler and the surrounding counties where the majority of the spring sample was obtained.

Echinostoma revolutum was most prevalent in wild turkeys collected in Butler County, and also was present in Cowley, Reno, and Jefferson counties. *Echinostoma revolutum* has a life cycle that includes lymnaeid snails as first intermediate hosts, prosobranch snails, mussels, turtles, and frogs as second intermediate hosts, and birds as definitive hosts (Kanev, 1994). Other suitable hosts for *E. revolutum* include rock dove (*Columba livia*), gallinaceous birds and, more commonly, waterfowl (Kanev, 1994). Hon et al. (1975) previously reported *E. revolutum* in wild turkeys from Florida. Kanev (1994), suggesting that previous studies, which reported the distribution of *E. revolutum* as cosmopolitan were based on incorrect identifications, cautioned against classifying *Echinostoma* species found in the United States as *E. revolutum*,. For the purpose of my study, the *Echinostoma* sp. found was classified as *E. revolutum* based on 37 collar spines and comparison with museum specimens. Prevalence and mean intensities of *E. revolutum* in the spring sample were higher than in the fall/winter sample. These differences could be due to differential prevalences of *E. revolutum* in collection areas or snail availability being lower in the fall/winter seasons when ephemeral pools and standing water are less abundant.

Cestodes - Cestodes were the most commonly encountered helminths in the present study. Four species of cestodes were found in the spring sample, and only two of these species were found in the fall/winter sample (Fig. 4.2). Both prevalence and mean intensities were high for cestodes encountered, particularly for *Metroliasthes lucida*. *Metroliasthes lucida, Imparmargo baileyi,* and *Raillietina* sp., which have been reported previously in wild turkeys (Table 4.2). However, this is the first report in wild turkeys from Kansas. *Choanotaenia* sp. previously have not been reported from wild turkeys, but they have been reported in other avian species.

Metroliasthes lucida, the most common cestode in the present study, was found in the following counties: Butler, Chase, Coffey, Cowley, Elk, Jefferson, Lyon, Marion, Pottawatomie, and Reno. *Metroliasthes lucida* is considered to be a common parasite of both wild (Maxfield et al., 1963; Prestwood et al., 1973; Hon et al., 1975; Sasseville et al., 1988) (Table 4.2) and domestic turkeys and has been found in domestic turkeys across the United States (Williams, 1931). *Metroliasthes lucida* uses an arthropod intermediate host (Prestwood et al., 1973).

Imparmargo baileyi was found only in the spring sample in Butler and Reno counties. This genus previously has been reported only in wild turkeys in West Virginia (Prestwood et al., 1973). The finding of *I. baileyi* in wild turkeys from Kansas constitutes an expansion of the parasite's known geographic range. Little is known about the life cycle of *I. baileyi*, but belonging to the Dilepididae, it presumably requires an arthropod as an intermediate host.

Choanotaenia sp. also was found only in the spring sample and only in Butler, Cloud, and Cowley counties. Members of the genus *Choanotaenia* require flies and beetles as intermediate hosts (Olsen, 1974). Species of *Choanotaenia* previously have not been reported in wild turkeys but are common parasites of domestic chickens and domestic turkeys and also have been reported in ring-necked pheasant from the panhandle of Texas (Pence et al., 1980).

The genus *Raillietina* frequently has been reported in wild turkeys across the United States (Table 4.2), and has been found in ruffed grouse from West Virginia (Davidson et al. 1977), and northern bobwhite (*Colinus virginianus*) from Florida (Moore and Simberloff, 1990). *Raillietina* sp. was found in both the spring and fall/winter samples and in the following counties: Butler, Coffey, Greenwood, and Lyon. *Raillietina* spp. require insects, particularly grain, dung, and ground beetles as intermediate hosts (Schmidt and Roberts, 2000). Prevalence and mean intensities were higher in the fall/winter sample, possibly relating to the time at which wild turkeys acquire this particular parasite.

Although mean intensities were similar between the spring and fall/winter sample, prevalence of *M. lucida* was higher in the spring sample. However, for *Raillietina* sp. the trend was of higher mean intensity in the fall/winter sample and similar prevalence in the spring and the fall/winter seasons. *Imparmargo baileyi* and *Choanotaenia* sp. were found only in the spring sample. These four cestode species share similar life cycles. Therefore, the observed higher prevalence of *M. lucida* in the spring sample and the absence of *I. baileyi* and *Choanotaenia* sp. in the fall/winter sample could possibly be explained by decreased abundance of arthropod intermediate hosts in the fall/winter season, as well as a shift in wild turkey diet to almost entirely plant matter during this time of year. However, cestode species found in the present survey use arthropods as intermediate hosts and this does not explain the observed patterns of prevalence and mean intensity seen for *Raillietina* sp. The seasonal differences observed in prevalence and mean intensity for *Raillietina* sp. might be explained by its specificity for its intermediate host. Perhaps *Raillietina* sp. uses an intermediate host that was present only at low levels in the fall/winter season and thus prevalence and mean intensities were lower. No data were collected with respect to arthropod abundance; therefore these seasonal differences could not be elucidated further.

Acanthocephalans - Only one acanthocephalan species, *Mediorhynchus grandis,* was found in a single wild turkey from Cloud County. Members of the genus *Mediorhynchus* are common parasites of galliformes and previously have been reported in wild turkeys in several states (Table 4.2), as well as in northern bobwhite from Florida (Moore and Simberloff, 1990). The life cycle of *M. grandis* includes cockroaches and presumably many other arthropods as intermediate hosts (Olsen, 1974).

Nematodes - Only one species of nematode was found in wild turkeys collected in Kansas. *Heterakis gallinarum* was found in birds harvested in Butler and Cowley counties. Previous surveys of wild turkey parasites have reported high numbers for both nematode species and individuals with *Ascaridia dissimilis, Capillaria* spp., *Trichostrongyloides tenuis*, *Dispharynx nasuta*, and *H. gallinarum* cited as the most common nematodes of wild turkeys (Gardiner and Wehr, 1949; Maxfield et al., 1963; Prestwood, 1968; Prestwood et al., 1973; Hon et al., 1975; Jackson et al., 1977; Castle and Christensen, 1984; Sasseville et al., 1988). One possible explanation for the low number of both nematode species and individuals found in the present survey is the egg embryonation requirements of nematodes. Many species require specific soil moisture levels for egg development (Hon et al., 1975) and these vary from species to species.

Heterakis gallinarum is a common cecal worm of wild turkeys (Table 4.2) and domestic poultry and its distribution is cosmopolitan (Schmidt and Roberts, 2000). *Heterakis gallinarum* previously has been reported in wild turkeys from several locations

(Table 4.2), as well as in ring-necked pheasant from the Texas panhandle (Pence et al., 1980). The life cycle of *H. gallinarum* is a direct life cycle, with embryonated eggs being ingested by the definitive host (Schmidt and Roberts, 2000). *Heterakis gallinarum* was found only in the spring sample, with relatively low mean intensities (Fig. 4.2). Finding *H. gallinarum* in Kansas wild turkeys is, however, of some importance to managers of wild turkeys. *H. gallinarum* is the vector for *Histomonas meleagridis,* which causes blackhead disease in both domestic and wild turkeys, a common galliform disease resulting in necrosis of the cecal mucosa, swelling of the ceca, and liver necrosis (Davidson and Wentworth, 1992). The low numbers of *H. gallinarum* and the lack of any visible signs of infection suggest that blackhead is not a problem in eastern Kansas at the present time.

Table 4.1. Seasonal prevalence (with upper and lower confidence intervals) of enteric helminths of wild turkeys from eastern Kansas.

Parasite species	USNPC #	Fall Prevalence %	Spring Prevalence %
Heterakis gallinarum	092455.00	0	11.4 < 12.2 < 24.7
Echinoparyphium recurvatum	092462.00	0.1 < 4.4 < 22	0.05 < 2.0 < 2.9
Echinostoma revolutum.	092463.00	0.1 < 4.4 < 22	6.0 < 14.3 < 18.0
Mediorhynchus sp.	092456.00	0	0.05 < 2.0 < 2.9
Metroliasthes lucida	092457.00	34.5 < 56.5 < 100	39.3 < 93.9 < 100
Imparmargo baileyi		0	1.3 < 6.1 < 14.3
Choanotaenia sp.	092459.00	0	11.4 < 12.2 < 24.7
Raillietina sp. (*Skrjabinia*)	092460.00	0.5 < 13.0 < 13.9	0.5 < 4.1 < 15.0

Fig. 4.2. Mean intensities of helminth parasite species from wild turkeys in Kansas in the spring and fall/winter samples (error bars indicate standard error); H= *Heterakis gallinarum*, E.r.= *Echinostoma revolutum*, Ec.= *Echinoparyphium recurvatum*, Me.= *Mediorhynchus grandis*, M.l.= *Metroliasthes lucida*, I= *Imparmargo baileyi*, C= *Choanotaenia* sp., R= *Raillietina* sp.

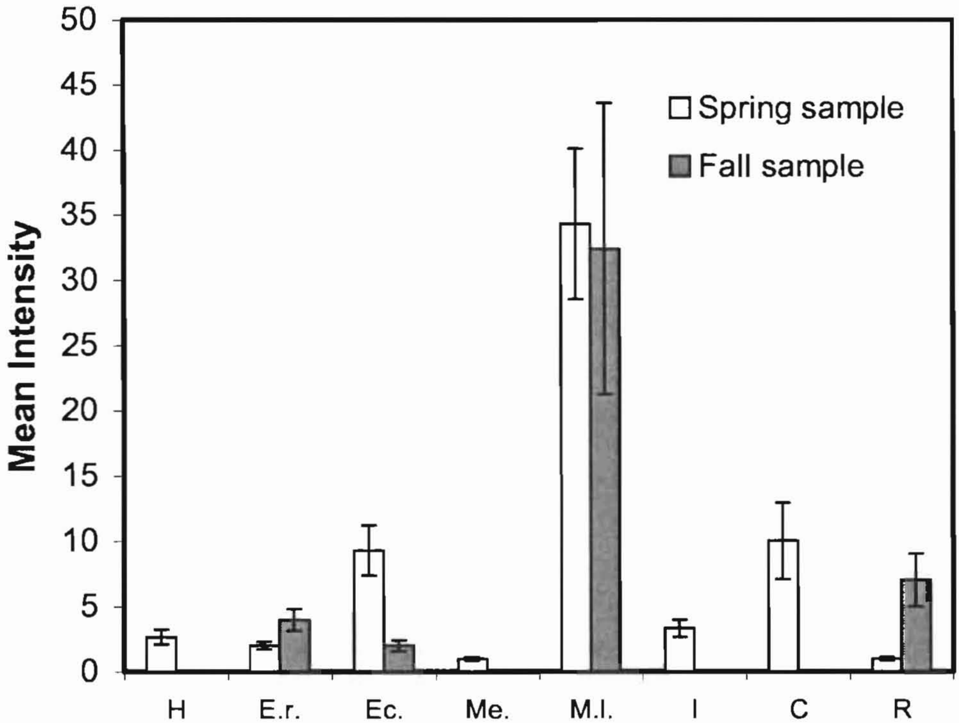

50
45
40
35
30
25
20
15
10
5
0
Mean Intensity
Spring sample
Fall sample
H
E.r.
Ec.
Me.
M.I.
I
C
R

Table 4.2. Previous reports of the enteric helminths of wild turkeys found in the present study.

Helminth	Distribution	Author(s)
ACANTHOCEPHALA:		
	SD	Huggins and Dauman, 1961
Mediorhynchus grandis	FL	Hon et al., 1975
	MS	Prestwood, 1968
	MS	Prestwood et al., 1973
NEMATODA:		
Heterakis gallinarum	FL	Hon et al., 1975;
	MS, FL, AL, GA, LA, MD, TN, VA, KY	Maxfield et al., 1963
	MS, AR, SC, WV	Prestwood et al, 1973
	KY	Castle and Christensen, 1984
	CT	Sasseville et al., 1988
	MS	Prestwood, 1968
	IL	Jackson et al., 1977

Helminth	Distribution	Author(s)
CESTODA:		
Metroliasthes lucida	FL	Hon et al., 1975
	FL, GA, KY, LA, TN, VA, AL, AR, MS	Maxfield et al., 1963
	CT	Sasseville et al., 1988
	MS, Al, AR, SC, WV	Prestwood et al., 1973
	MS	Prestwood, 1968
	RI	Amr et al., 1988
Imparmargo baileyi	WV	Davidson et al., 1974
TREMATODA:		
Echinoparyphium recurvatum	MS	Prestwood, 1968
	MS, AR, SC	Prestwood et al., 1973
	AL, FL, LA, MS, TN	Maxfield et al., 1963
	OK	Self and Bouchard, 1950
	FL	Hon et al., 1975
Echinostoma revolutum	FL	Hon et al., 1975

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CHAPTER FIVE
SUMMARY

The preceding chapters provide insight into the dynamics of wild turkey (*Meleagris gallopavo*) populations in Kansas, as well as the overall health of these populations with respect to the enteric helminths they harbor. The evidence suggests that the wild turkey population in Kansas is a healthy, rapidly expanding population with the potential to reach high densities. Agricultural practices and conservation programs in the state of Kansas have provided thousands of hectares of suitable habitat that meet the requirements of the wild turkey for reproduction, brood-rearing, and survival. However, as the human population continues to grow and expand into rural areas, large populations of any animal can cause many social conflicts.

The results of the analysis of Rural Mail Carrier Survey (RMCS) data indicate that the wild turkey population in Kansas is growing exponentially in all regions of the state, with the exception of the southwestern corner where the wild turkey population is exhibiting no growth at the present time. The observed growth pattern of the wild turkey population in Kansas is interpreted as the spread of existing populations and the subsequent establishment of new populations, which would explain the east-west gradient in growth rates, as riparian areas containing suitable roost trees decline as you move westward across Kansas. The observed growth rates in the western half of the state suggest that wild turkey populations might have reached the western edge of their range in Kansas. If preemptive competition for roost trees and not factors such as available forage and nutrients limit wild turkey expansion, the state population should approach carrying capacity smoothly.

The observed fluctuations in wild turkey relative abundances are interpreted as variations in population growth related to nest success. Correlations between winter precipitation and the residuals in the northern regions of Kansas indicate that available nesting cover, which is limited by the amount of winter rainfall, can limit populations of wild turkeys in these regions. Nesting cover in the southern regions presumably is limited by some other climatic factor. The correlation of these annual non-random fluctuations among adjacent regions, responding to the same environmental factors, as predicted by Moran (1953) for populations speak to the internal consistency of the RMCS summer data and thus the use of the RMCS as a tool for tracking the long-term dynamics of game animals.

A sound management plan is required to prevent wild turkey populations from reaching their wildlife acceptance capacity (Decker and Purdy, 1988) or becoming so large that they are susceptible to disease outbreaks. Most of the helminths found in wild turkeys from Kansas have little or no associated pathology, with the exception of *Heterakis gallinarum*. Since *H. gallinarum* serves as the vector for blackhead disease, which can cause high mortality in wild turkeys (Davidson and Wentworth, 1992), and is present in wild turkeys in Kansas, the potential does exist for wild turkey populations in Kansas to be regulated by a disease such as blackhead. *Heterakis gallinarum* also can be detrimental to other galliform game birds. Management plans for the wild turkey in Kansas need to take into account the potential risks associated with *H. gallinarum* and encompass harvest regulations that prevent wild turkey populations in Kansas from becoming too dense.

The results of the present investigation provide valuable tools that can be used to approach the problem of disease and parasites within turkey populations. The results of the PCA of epigamic characters revealed two orthogonal principal components that can be used to monitor wild turkey population health: characters associated with age and vigor that presumably are not responsive to stochastic events such as disease or pathogens and were correlated with the first PC, and snood length and skullcap width, which were correlated with the second PC. The latter two characters possess the potential to respond to pathogens (Buchholz, 1995) and thus can be used to assess a population's overall health in response to stochastic events. The fact that females assess males based on these two characters Buchholz (1995), provides substantial support for the utilization of these two characters.

The proposed rezoning of spring turkey hunting zones and increases in spring bag limits where turkeys have reached their wildlife acceptance capacity should produce a level of harvest that better tracks the observed growth of the wild turkey populations in these zones. Moreover, the proposed zones take into account the wild turkey abundance in these regions, which should prevent the wildlife acceptance capacity of wild turkeys from being reached.

In conclusion, the results of the present study indicate that Kansas has a healthy and growing wild turkey population. The results also suggest that the Kansas Department of Wildlife and Parks (KDWP) needs to revisit current management practices for wild turkeys in Kansas in order to ensure a healthy population of wild turkeys for a sustainable harvest for future generations of turkey hunters. The results also indicate that Rural Mail Carrier Surveys (RMCS) have the potential to provide reliable indicators of a species' relative abundance that will facilitate effective management plans.

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