USING AVHRR SATELLITE DATA TO MODEL PHEASANT POPULATIONS TRENDS IN NORTHWEST KANSAS

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ABSTRACT

In an effort to explain past and predict future fluctuations in the ring-necked pheasant *(Phasianus colchicus)* population, ten years of Advanced Very High Resolution Radiometer (AVHRR) satellite imagery and pheasant population estimates from Rural Mail Carrier (RMC) Surveys were analyzed for six counties in northwestern Kansas. Jacknife linear regression models were built on a county-by-county basis and using all six counties as one aggregate unit. Results showed that county specific models were more successful in predicting pheasant populations, indicating different land cover and land management practices were having different impacts on the local pheasant populations. The county-level regression models were applied to out-of-sample data for 1999 and 2000. Out of sample results showed 10 of the 12 predictions were within a 90% confidence interval around the pheasant population index.

INTRODUCTION

To monitor wildlife populations, resource managers need reliable population data. Unfortunately, timely manual counts of wildlife populations inhabiting large geographic areas are costly, inefficient, and difficult or impossible to conduct. Therefore, it is necessary for ecologists to use a variety of indices to estimate animal populations and monitor trends. While these indices provide information about the number of animals present in a given area, they do not assess the relationship between wildlife and their habitat. It is the goal of this study to use ring-necked pheasant population indices and satellite derived vegetation measurements to identify relationships between pheasant population trends and the environmental conditions. The results of this analysis may provide resource managers with a useful tool for predicting and monitoring pheasant populations.

Pheasant populations in Kansas have been monitored by Rural Mail Carriers (RMC) four times annually since 1966. The mail carriers record the number of pheasants observed and the number of miles driven during each of the observation periods in January, April, July, and October. The RMC data allows researchers to calculate pheasant indices and provides an indication of the population trends of pheasants and other wildlife in Kansas. Rodgers (1999) analyzed the historical records and found an average of 9.30 pheasants/161 km between 1966 and 1975. This density decreased to 7.28 pheasants/161 km in the late 1970's and early 1980's, and continued to decrease to an average of 3.28 pheasants/161 km in the late 1980's and early 1990's. Rodgers (1999) provides additional

Houts, M.E., K.P. Price, and R.D. Applegate. 2002. Proceedings, XXII FIG International Congress ACSM-ASPRS Conference and Technology Exhibition2002, Washington, DC. 7 pp.

information to show that the decrease was not constant, but rather occurred in two large declines. The first decrease occurred between 1973 and 1976, however, pheasant populations recovered to near their previous level by the late 1970's. The second rapid decrease occurred following a drought and the subsequent severe winter in 1983, from which the pheasant population has never recovered.

Factors influencing western Kansas pheasant populations include the early spring quality of green winter wheat relative to the quality of wheat stubble nesting sites, timing of spring tillage, timing of summer harvest, and nest predation. Spring tillage and the application of herbicides and pesticides to wheat stubble have been shown to have negative impacts on pheasant populations by disturbing nests (Rodgers 1983) and reducing the fields production of weeds that provide pheasants with food and shelter (Rodgers 1994, Sotherton and Robertson 1990, Chiverton 1999). Tillage occurring from mid-April to mid-June destroys many pheasant nests in wheat stubble, especially in years where spring stubble is of better quality than green wheat. A study in Northeast Colorado found that spring tillage destroyed more nests (11) then were lost to predators (5) (Snyder 1984). Additionally, when forced from stubble fields by spring tillage, nearly all hens relocated to green wheat fields in an attempt to re-nest, unfortunately their second nesting attempt is also often unsuccessful as a result of wheat being harvested in mid summer. Snyder's (1984) study also indicated that in 1979, had wheat harvest been one week earlier, one third of the 13 successful nests would have been destroyed. Conversely, in 1981, if wheat harvest had been delayed one week, half of the 10 nest failures would have potentially hatched. From these accounts of tillage and harvesting damage, it seems apparent that the phenological state of the vegetation, which influences the timing of agricultural activities, can have a dramatic impact on pheasant populations.

Many studies have used satellite data captured with the Advanced Very High Resolution Radiometer (AVHRR) sensor aboard the National Oceanic and Atmospheric Administration's (NOAA) satellite series to monitor vegetation (i.e., Justice *et al.*, 1985; Prince and Tucker, 1986; Hielkema *et al.*, 1986; Maselli *et al.*, 1993; Batista *et al.*, 1997; and others). The use of remote sensing to monitor vegetation condition provides a unique opportunity to evaluate the relationship between vegetation conditions and the status of wildlife populations. Since wildlife populations are dependant on vegetation for food and cover, determining a measurable and predicable relationship between vegetation condition and wildlife population status could provide wildlife biologists with a valuable resource management tool.

STUDY AREA

This study was conducted in Thomas, Sheridan, Graham, Logan, Gove, and Trego counties in northwest Kansas (Figure 1). These six contiguous counties can be characterized as having a semi-arid high plains climate with a flat to rolling agriculture/grassland landscape with few trees, except for in shelter belts and riparian zones. The region is dominated by cropland, however, relatively large tracts of pasture and Conservation Reserve Program (CRP) land are found throughout the area. Overall, the area is 64% cropland and 36% grassland, with individual counties ranging from 53 % cropland and 47% grassland (Trego County) to 64% cropland and 36% grassland (Thomas County)(Table 1). Other cover types such as urban and riparian are present, but do not make up a large proportion of the landscape. The grasslands in the area are dominated by little bluestem (*Andropogon scoparius*) western wheatgrass (*Bouteloua smithii*), blue grama (*Bouteloua gracilis*), and buffalo grass (*Buchloe dactyloides).* Winter wheat is the dominant crop in the region, but corn, sorghum, and domestic sunflowers are also common. The last decade has shown a decrease in wheat planted from about 950,000 acres to about 830,000 acres, and a steady increase in corn planted from about 100,000 acres to about 300,000 acres (USDA NASS).

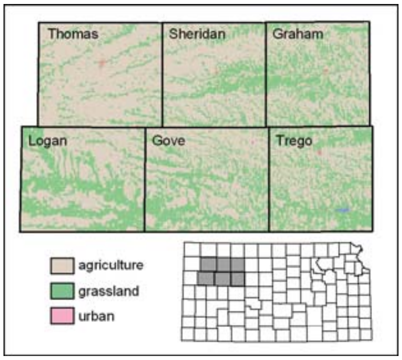

Figure 1. Six counties in northwest Kansas where pheasant population trends were examine in relation to vegetation data.

Table 1. Percentage of each county covered by grassland or cropland as mapped by the Kansas Land Cover Map and resampled to one kilometer.

County	% Grassland	% Agriculture
Trego	47	53
Logan	43	57
Gove	40	60
Graham	40	60
Sheridan	30	70
Thomas	17	83
overall	36	64

METHODS

Pheasant indices for each county were derived from RMC data collected in January, April, July, and October of each year 1989-1998. The raw data were converted to index values (pheasants/161 km) by dividing the total number of pheasants observed by the total number of kilometers driven on the mail route. The yearly pheasant indices for each county were then obtained by averaging the four seasonal indices. The averaging was done to reduce any errors introduced by seasonal fluctuations in pheasant visibility or the abilities of the individual mail carriers to spot pheasants. The averaging of multi-season values also helped buffer inter-annual fluctuations, and helped eliminate erratic population values. The average yearly pheasant indices for each county were then examined for possible relationships among counties or among years. In an effort to explain past and predict future pheasant population fluctuations, pheasant density values were compared to variables derived from NOAA AVHRR satellite data.

The AVHRR data we used consisted of 10 years (1989-1998) of bi-weekly Normalized Difference Vegetation Index (NDVI) data. The NDVI is strongly correlated with chlorophyll concentrations and therefore provides information about the condition of the vegetation (i.e., “greenness”, phenological stage, biomass). The NDVI data were further processed to calculate the Vegetation Phenology Metrics (VPM) to quantify several features associated with vegetation development including: 1) the onset date of plant green-up, 2) the NDVI value at the time of plant green up, 3) the amount of accumulated NDVI (biomass) by late April and, 4) the accumulated NDVI by the middle of June. Green-up is defined here as the time of plant emergence or the time when plants begin to increase biomass production at the end of winter dormancy. These phenology metrics were selected for analysis because they measure the phenological state and biophysical conditions of vegetation at times critical to pheasant survival such as hatching date, and the timing of agricultural activities (i.e., tilling, undercutting, planting, harvesting). To compare the AVHRR data with the RMC data, the average data value for all pixels within a county were considered.

The 10 years of AVHRR data (NDVI and VPM) and the average yearly pheasant index for each county were entered into a spreadsheet and analyzed using SPSS and MATLAB software. A Kolmogorov-Smirnov test and t-test were conducted on the 6-county aggregate and on individual counties to test if the data were normally distributed and contained significant differences. A program was written in MATLAB to perform a linear regression on the average pheasant densities (dependent variable) using all possible two variable combinations of AVHRR data (independent variable) from the same year. A total of 7,650 Jacknife regressions (1,275 per county) were run on the county-level data. The results of the regressions were ranked based on the adjusted root mean square error (RMSE) values from each model. The models with the lowest RMSE (for the aggregated area and for each county) were selected and applied to the ten-year data set. The robustness of the model was tested using the best model to predict pheasant populations for each county and the aggregated area for out-of-sample years 1999 and 2000. The resulting predictions were compared to RMC observations for these two years.

RESULTS

The average yearly pheasant indices, as calculated from RMCS data, showed considerable differences in pheasant populations between years and between counties (Figure 3). The ten yearly averages for each county were analyzed using the Kolmogorov-Smirnov test and all six counties were found to have a normal distribution of pheasants through the years. A t-test performed on the average pheasant indices for each county revealed the counties were divided into two groups. Logan and Sheridan Counties were not significantly different from one another, but were significantly different from the other counties (Gove, Graham, Thomas, Trego), which were not significantly different from one another. additionally, it was found that there was generally not a high degree of correlation in the yearly average number of pheasants between counties (Table 2). This is not to say that the pheasant populations in each of the counties were responding completely

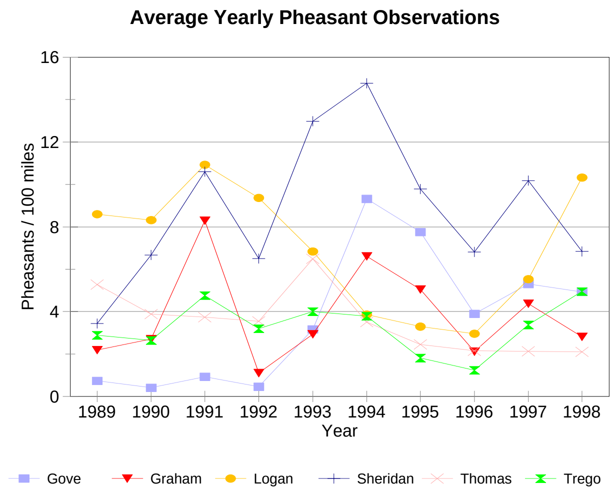

Figure 3. Mean annual pheasant observations for each county.

Table 2. Correlations (r^2) of average pheasant populations between counties taken from (1989-1998).

	Gove	Graham	Logan	Sheridan	Thomas	Trego
Gove	1.00	.396	-.704	.616	-.417	-.067
Graham	.396	1.00	-.057	.659	-.113	.374
Logan	-.704	-.057	1.00	-.366	.274	.684
Sheridan	.616	.659	-.366	1.00	.113	.324
Thomas	-.417	-.113	.274	.113	1.00	.219
Trego	-.067	.374	.684	.324	.219	1.00

different from one another, as there were some years where the population in all counties behaved similarly (1994-1996 all populations decreased). The cause for these differences and similarities remains unknown, however it is possibly due to differences in the abilities of RMC observers and/or differences in the proportions of land cover types, crop rotations, and land management practices.

Attempts to create a single model that accurately captured pheasant trends in all six counties were unsuccessful. The best regional model had a $r^2 = 0.52$ and an adjusted RMSE = 2.41. This model was only able to roughly predict pheasant population trends in some counties, and was very unsuccessful in others. Efforts to create county specific pheasant population models were more successful than regional modeling attempts. When the RMSE values for each of the 1,275 Jacknife regressions per county were ranked in ascending order, it was found that the models with the lowest error were different for each county (Table 3). These differences appear to be related to the dominant landuse/landcover found within the county. The two counties with the highest percentage of cropland used variables that corresponded to important dates in the growing season of the dominant crop types of the county. Models for Thomas County (dominated by wheat) worked best when NDVI from the middle of February and the middle of July were used. Sheridan County, which has nearly equal acres of wheat and corn, was best modeled using NDVI data from the middle of July and the middle of October. These dates represent harvest times for wheat and corn, respectively, and appear to have significant implications on the availability and quality of pheasant nesting and brood rearing habitat. Trego and Logan counties, on the other hand, have the largest area of grassland, 47% and 43% respectively, with the remaining percentage of cropland dominated by wheat. Perhaps because these two counties are nearly half cropland and half grassland, the two counties do not use models that can easily be related to the vegetation. Trego County was best modeled using NDVI data from the end of February and the beginning of March, while Logan County was best modeled using data from the middle of August and the middle of October.

Table 3. NDVI variables used in models and corresponding error measurements for modeling pheasant population in each county.

County	Variable 1	Variable 2	Jacknife RMSE	Jacknife r2	In-sample r2
Gove	mid July	mid September	2.43	0.53	0.69
Graham	late January	early September	2.08	0.45	0.76
Logan	mid August	mid October	1.86	0.67	0.76
Sheridan	mid July	mid October	1.63	0.82	0.89
Thomas	mid February	mid July	0.52	0.89	0.93
Trego	late February	early March	0.92	0.50	0.59

When historic AVHRR data from 1989-1998 were entered into the regression equations for each county, all of the in-sample models were able to accurately predict (within a 90% confidence interval) the mean yearly number of pheasants as reported by the RMCS. Furthermore, only two predictions (Gove County 1994, and Trego 1991) were outside the 95% confidence interval. When the selected AVHRR variables were entered into the regression equation for out-of-sample model validation using data from 1999 and 2000, the results were inconsistent with the previous levels of accuracy. Of the twelve new predictions (six counties for two years) five predictions were within one standard deviation, five within two standard deviations and two were beyond two standard deviations (Figure 4).

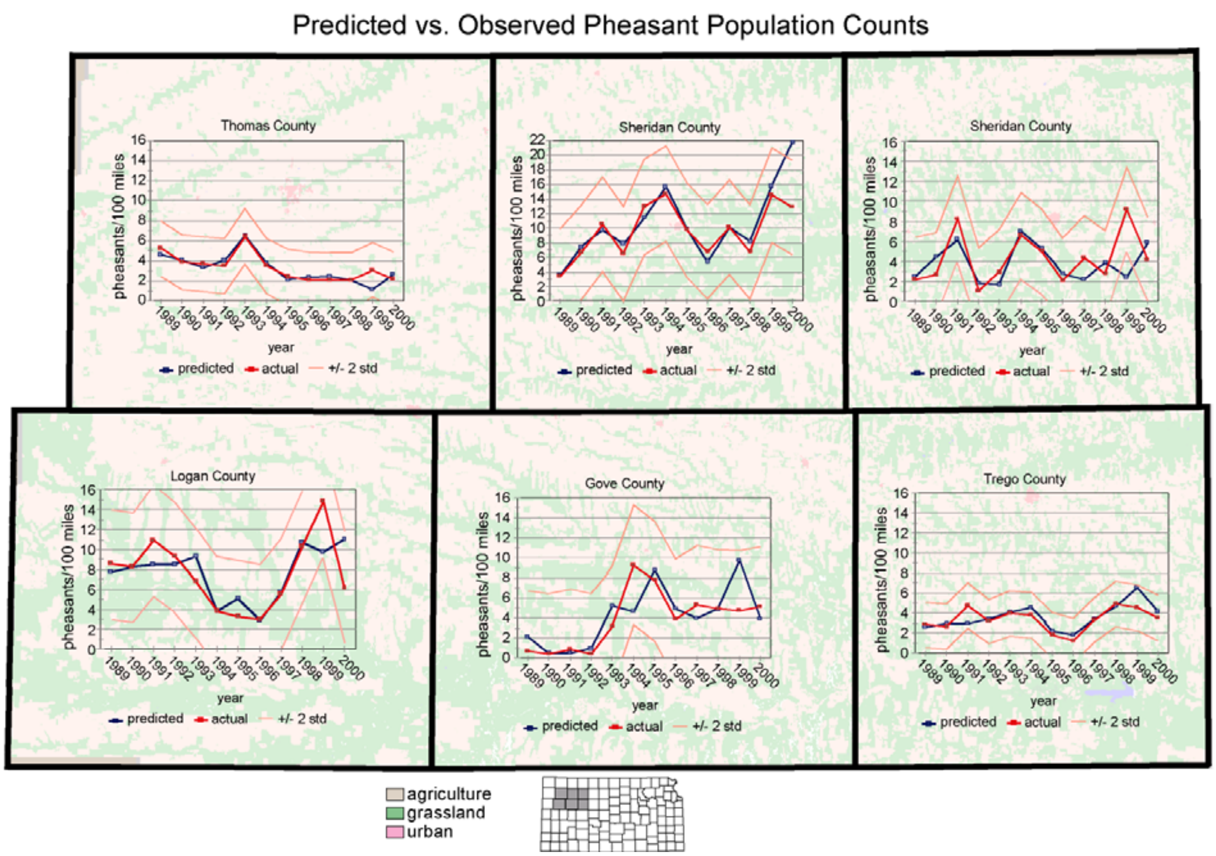

Figure 4. Results of jacknife linear regression models showing predicted versus actual number of pheasants per county. Predictions from 1989-1998 show in sample regression results, while predictions for 1999 and 2000 were made using out-of-sample data.

DISCUSSION

The fact that pheasant populations appeared to be responding to different variables in each county may be an indication of how pheasants respond to the different land cover patterns and land management practices present in each county. In general, pheasants are found more often on cropland than grasslands during fall and winter months. Rodgers (1999) explained that some possible reasons for this preference include the abundance of waste grain available after crops have been harvested, the ability of weedy wheat stubble to provide sturdy shelter in strong winds and snow as well as well as protection from avian predation, and the low amount of accumulated liter allows easy movement. By contrast grasses generally provide less food, offer less resistance to avian predators due to their flexibility, and have an abundance of accumulated litter that hinders pheasant movement.

The recent trend towards no-till or low-till farming has resulted in increased soil moisture that has allows farmers to plant more corn than in previous years. In addition to the changes in acreage planted to different crops, the change in tillage and herbicide practices have also changed the characteristics of crop stubble left in the field. In the early 1980's weedy wheat stubble comprised the majority of post harvest wheat fields in western Kansas, however by the late 1990's weedy wheat stubble was rare (Rodgers 1999).

In order to adequately use NDVI and associated satellite data as a tool to predict pheasant populations, models will have to be built on a county-by-county basis. Landscape-scale differences in land use and land cover across the western Kansas pheasant range and their relationship to pheasant populations are still poorly known. Source-sink dynamics (Pulliam 1996) can complicate the relationship between population indices and satellite data. Further research is needed to clarify pheasant population dynamics and land use, the relationship of land use-land cover and NDVI, and the relationship between pheasant production and plant phenology.

ACKNOWLEDGEMENTS

This research was funded by the Kansas Department of Wildlife and Parks and National Aeronautics and Space Administration (NASA). Dr. S. A. Williams, Secretary of KDWP, and Keith Sexton, Acting Assistant Secretary KDWP, supported and facilitated funding of this research. We also wish to express appreciation to the Kansas Applied Remote Sensing (KARS) Program and the Department of Geography at the University of Kansas for their support facilities and personnel. J. C. Riffer assisted with organizing the RMC data. W. E. Jensen, D. A. Robinson, Jr., R. Schilowsky, S. Finkbeiner, and K. Van Why assisted with data entry and other support. The RMC data are the result of cooperation from hundreds of Kansas rural mail carriers who voluntarily supply this data 4 times/year; they are gratefully acknowledged for this effort. We also thank all of the KDWP personnel past and present that coordinated, collated, and mailed RMC materials. The RMC is a contribution in part of Federal Aid Grant W-39-R and its predecessors.

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