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CLIMATE-BASED NEURAL MODELS OF RIO GRANDE TURKEY PRODUCTIVITY IN TEXAS

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Abstract: We used neural-network modeling to assess the effects of weather and climate variables in predicting production (poults:hen ratios) of Rio Grande turkeys (*Meleagris gallopavo intermedia*) in Texas. We used poult:hen data from Texas Parks and Wildlife (TPWD) surveys collected by TPWD biologists during 1977 through 2003. Datasets contained seasonal rainfall and temperature data, deviations from long-term mean rainfall and temperature, or Modified Palmer Drought Severity indices for winter (Dec–Feb), spring (Mar–May), summer (Jun–Aug), and fall (Sep–Nov). We used the adjusted sum-of-squares for model selection. The model with the best performance included deviations from long-term mean conditions as predictor variables. The selected model accounted for 28% of the variation in the training data. Wetter than normal years, and particularly springs, resulted in declines in poults:hen ratios. Warmer than normal winters and falls resulted in increases in poults:hen ratios. Based on ecoregion-level means, climate conditions in the Edwards Plateau are best for turkey production; the model predicted 1.71 poults/hen for the Edwards Plateau compared with 1.43 based on statewide climate conditions. Our analysis provisionally supported the hypothesis that deviations from normal conditions best explain annual fluctuations in production. However, we were not able to rule out the possibility that weather catastrophes play a significant role.

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Key words: climate, ecoregion-level analysis, *Meleagris gallopavo intermedia,* neural network model, Rio Grande wild turkey, Texas, weather.

A detailed understanding of the factors influencing the population dynamics of the Rio Grande turkey is essential for successful management. Although precipitation is 1 factor thought to influence the population dynamics of eastern wild turkeys (*M. g. silvestris*; Healy 1992, Hohensee and Wallace 2001) relatively little is known about the factors influencing Rio Grande turkeys. Miller et al. (1995) hypothesized that spring and early summer rainfall influence the vegetation community in which Rio Grande turkeys nest, resulting in the higher survival rate of hens incubating second and third nests they observed in Kansas. For the eastern subspecies, little or no production occurs during drought years (Healy 1992) and nest success in Mississippi was negatively related to the number of rainfall events and cumulative rainfall (Lowrey et al. 2001).

Healy (1992:137) noted, ‘‘Extreme local variation

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in effects of weather seems to be a general phenomenon in turkey populations.'' Such variation makes broad-scale analyses of the effects of weather ineffectual. Therefore, an ecoregional analysis of the effects of climate and weather on poult:hen ratios in Texas was undertaken. Our objectives were to provide descriptive data on the effects of climate on production and to better understand the relative effects of weather and climate on Rio Grande turkey poult:hen ratios using neural network models. The knowledge gleaned from such models should allow managers to more effectively manage populations within a particular climate or weather context. Our analysis also allowed us to test the hypothesis that departures from normal conditions better explain annual variability in turkey production than yearly weather conditions (Bailey and Rinell 1968).

METHODS

Our analysis was based on data collected in Texas. Texas counties were grouped into 10 ecoregions: Pineywoods, Gulf Prairies and Marshes, Post Oak Savannah, Blackland Prairies, Cross Timbers, South Texas Plains, Edwards Plateau, Rolling Plains, High Plains, and Trans-Pecos Mountains and Basins (Gould 1975). Poult:hen data for Rio Grande turkeys were available for 8 of those 10 ecoregions (all except Pineywoods and High Plains), so we focused on those 8 ecoregions.

Annual rainfall in Texas ranges from <200 mm in the Trans-Pecos to 1,400 mm in the Gulf Prairies and Marshes on the Louisiana border. The annual frost-free period ranges from 179 days in the northwest Texas Panhandle to 330 days in the lower Rio Grande Valley (Gould 1975).

Wild Turkey Data

We obtained poult:hen data from TPWD summer turkey surveys. These surveys were conducted in the Trans-Pecos, Rolling Plains, South Texas Plains, Edwards Plateau, Post Oak Savannah, and Cross Timbers ecoregions during 1 June–15 August, 1977 through 2003. Counts were conducted incidentally to the normal duties of TPWD biologists and were recorded on prepared forms to show county, date, number of turkeys observed, and number of adults and poults. Observers were asked to observe 10–25 hens/county during the survey period. We modeled poult:hen ratios as poults per total hens observed using the raw count data from those surveys.

Weather and Climate Data

We differentiated weather, the short-term rainfall and temperature regimes in a given locale within years, from climate, the long-term patterns in precipitation and temperature across years. We obtained climate and weather data from the National Climate Data Center, compiled by EarthInfo (Boulder, Colorado, USA). We selected weather stations with records ≥95% complete over the period of interest from 5 counties in each ecoregion. We used this method of weather station selection because surveys were not systematic, but occurred incidentally during the normal duties of TPWD biologists and, therefore, there were no set survey routes or points to which weather stations could be assigned based on proximity.

Weather data were extracted from NCDC records and summarized to obtain total monthly precipitation and mean maximum daily temperature for each month. These values were then averaged within ecoregions to obtain a single ecoregion mean. We used these data to estimate mean total seasonal precipitation and mean seasonal maximum daily temperature. Season classes were winter (Dec–Feb), spring (Mar–May), summer (Jun–Aug), and fall (Sep–Nov). Climate data were obtained by averaging the weather records over the entire period of record (range: 30–100 years) and subtracting the yearly weather values. Therefore, the climate data represented the deviation of annual weather conditions from the long-term mean conditions of the ecoregion. We also summarized the Palmer Drought Severity Index (PDSI) from NCDC records to obtain seasonal estimates. Because surveys were conducted during June–August each year and because some research suggested that, at least of eastern wild turkeys, previous fall rainfall affected turkey production (Healy 1992:136), we used previous fall rainfall and temperature as predictors in our models.

We created 4 datasets from the extracted data. The first dataset contained weather data. As defined previously, these data represented the mean annual rainfall and temperature observed at weather stations during the year of record. The second dataset contained the climate data. It quantified the magnitude of difference between annual conditions and the long-term climate means. We used those first 2 datasets to determine whether climate or weather patterns were the predominant factor influencing Rio Grande turkey production. The third dataset contained seasonal and annual estimates of the PDSI. We included this dataset because some research has indicated the PDSI better represents the effects of weather than simple temperature and precipitation in models of population abundance of some species (e.g., Northern Bobwhites *Colinus virginianus*; Bridges et al. 2001). Finally, the fourth dataset was a compilation of the important variables identified during the analysis of the other 3 datasets.

Modeling and Analysis

We used a neural network model (Smith 1996, Fielding 1999) to determine the relationship between poult:hen ratios and weather, climate, and the PDSI. Neural networks were implemented using Statistica Neural Networks (StatSoft, Tulsa, Oklahoma, USA). We used a 3-layer perceptron architecture and a hyperbolic transfer function. We allowed the program to determine model complexity (number of neurons) automatically based on relative performance of each model trained. We systematically partitioned the data into training and testing datasets by ordering the data by the dependent variable and selecting every fifth case. Using this process we set aside 20% of the overall data for assessing the model performances. Testing data were used to assess performance, but were not used for training the neural models. Performance was gauged by comparing the correlations between predicted and observed poult:hen ratios. We wanted models with strong, positive correlations between training and testing datasets. This ensured that the selected model accurately encapsulated the underlying relationships among variables and that the model could generalize to new data. We compared climate, weather and PDSI models using the adjusted sum-of-squares (Hilborn and Mangel 1997).

We created a series of datasets in which the independent variable of interest was allowed to vary between the minimum and maximum observed values while all other independent variables were held constant at their mean value. These datasets were then processed by the trained neural model and the predicted poult:hen ratio was plotted against the range of the variable of interest. These results were then used to interpret the model output.

The relative contribution of each variable to model predictions was determined by calculating a relevance score of each variable (Goodman 1996, Özesmi and Özesmi 1999). A relevance score is a measure of relative influence of each variable over the final prediction and is calculated as the sum of squared connection weights of the variable of interest (where connection weights link each variable to each neuron) divided by the sum of squared connection weights of all variables. If all of the independent variables had no effect on the dependent variable, we would expect them to have similar relevance scores. That is, each variable would have the same influence over the model's predictions because none of the predictors would be related to the response. We report simulations for only the variables which had greater than expected relevance scores.

To investigate ecoregion variation in the response of poult:hen ratios to climate, weather, and drought severity, we estimated the ecoregion means for each independent variable and presented these means to the trained neural model (cf. Lusk et al. 2002). The technique we employed shows regional responses based on the general statewide model.

RESULTS

Neural model performance varied among datasets. For Rio Grande turkeys, models for weather and PDSI datasets performed poorly. The best performing weather model contained 3 neurons and accounted for 23.2% of the variation in the training data, but only 6.5% of the variation in the testing data. Similarly, the best performing model based on the PDSI contained 3 neurons and accounted for 25% of the variation in the training data, but only 1.3% of the variation in the testing data. The neural model based on climate data performed better; the best model contained 2 neurons and accounted for 28% of the variation in the training data and 22% of the variation in the testing data.

Table 1. Relevance scores (%) for independent variables used to predict Rio Grande turkey production (poults/hen) in Texas, 1977–2003. The relevance of a variable is a measure of the relative influence of the variable on model predictions. The expected relevance assuming all variables to have an equal influence on model outcome was 11.1%.

Variable	Relevance (%)
Deviation from mean total annual precipitation	15.0
Deviation from mean total winter precipitation	12.1
Deviation from mean total spring precipitation	17.8
Deviation from mean total summer precipitation	5.9
Deviation from mean total fall precipitation	4.7
Deviation from mean maximum winter temperature	14.9
Deviation from mean maximum spring temperature	5.0
Deviation from mean maximum summer temperature	4.4
Deviation from mean maximum fall temperature	20.2

Using the relevance score, we selected variables from each of the 3 datasets and created a fourth dataset. There were 4 variables included in this model: summer PDSI, mean total spring rainfall, deviation of spring rainfall from normal, and deviation of fall temperature from normal. The best performing neural model containing these variables contained 3 neurons and accounted for 20.5% of the variation in the training data and 19.7% of the variation in the testing data. The climate model had a lower adjusted sum-of-squares (1.94) than the relevant-variable model (2.2), so we used the climate model for simulations and ecoregion analyses.

The expected relevance of each variable given no relationship was 11.1% for the climate model. Using this as a cutoff threshold, we found that 4 variables had a greater influence on model outcome than expected and 1 variable was within 1% of the threshold (Table 1). Deviation from long-term mean maximum fall temperature had the greatest influence on model outcome and deviation from long-term summer temperature had the least influence (Table 1).

As total annual precipitation increased above normal, poults:hen ratios declined (Figure 1). The same pattern held for spring precipitation, poults:hen ratio was highest (2.5 poults/hen) when precipitation was approximately 80 mm less than the long-term average (Figure 2). When mean winter temperature was above normal the poult:hen ratio increased and when below normal the poult:hen ratio decreased (Figure 3). Similarly, poult:hen ratios increased with increases in mean fall temperature above normal and declined with decreases in mean fall temperature below normal (Figure 4).

Using the mean climate data for each ecoregion as inputs into the neural model resulted in poult:hen ratios that would be expected given the general climate in each ecoregion. We contrasted the predictions for each ecoregion with that produced from statewide means. Given statewide climate averages, the neural model predicted that production would equal 1.44 poults/hen. The Edwards Plateau region had the highest predicted poult:hen ratio based on average climate

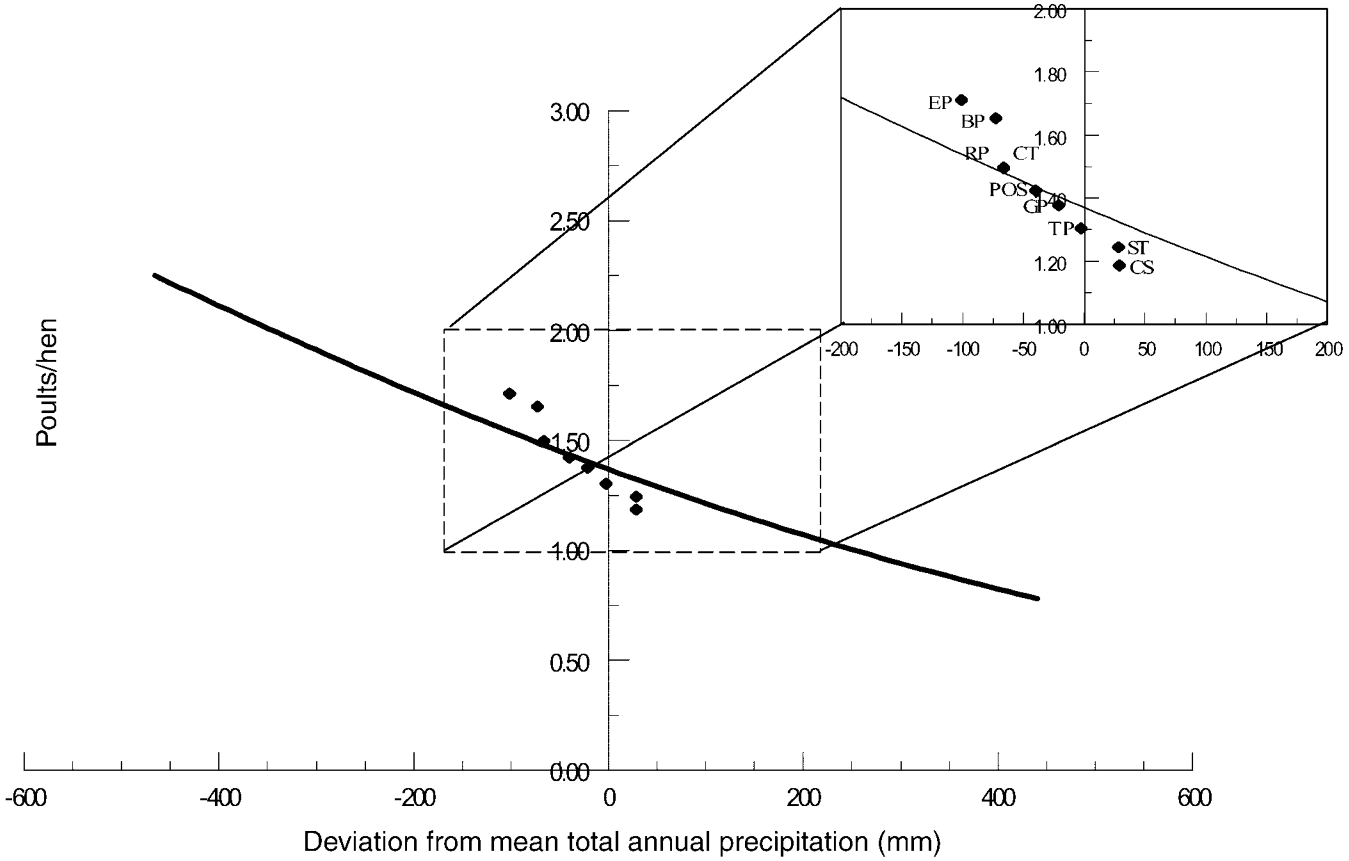

Fig. 1. Rio Grande turkey production (poults/hen) in Texas as a function of the deviation of total annual precipitation from the long-term mean. Inset shows the predicted poult:hen ratios for each ecoregion based on the long-term ecoregion means. Ecoregion abbreviations are as in Table 2.

conditions in the ecoregion (1.71 poults/hen; Table 2). Predicted poult:hen ratios were smallest for the South Texas Plains (1.24; Table 2). Overall, 4 ecoregions had predicted poult:hen ratios that were greater and 4 ecoregions had predicted poult:hen ratios that were smaller than that predicted from statewide climate (Table 2).

Of the 4 variables that were influential in the neural model, only deviation from mean total annual precipitation seemed to be related to the variation in predicted poult:hen ratios among ecoregions (Figures 1–4 inset). The Edwards Plateau had the largest negative deviation in mean total annual precipitation and had the largest poult:hen ratio (Table 2, Figure 1 inset). Each subsequent ecoregion had a smaller negative deviation and a smaller resulting poult:hen ratio (Figure 1 inset). The South Texas Plains, which had a positive deviation in mean total annual precipitation, had the smallest predicted poult:hen ratio, smaller than the predicted ratio based on statewide climate (Figure 1 inset). A similar pattern was apparent for spring precipitation (Figure 2 inset), except that the Blackland Prairies had a mean positive deviation from long-term conditions that was greater than that for the South Texas Plains, yet the predicted poult:hen ratio for the Blackland Prairies was the second highest of all ecoregions (Figure 2 inset).

MODELING CAVEATS

The nature of the data and of the analyses requires that we address some caveats to the interpretation of results. First, there is a lack of information on the accuracy of convenience sampling used to obtain the hen:poult data. Such data are commonly used by state management agencies for tracking turkey abundance (Kurzejeski and Vangilder 1992). Wunz and Shope (1980) found that survey data for eastern turkeys were well correlated with fall harvest in Pennsylvania. DeArment (1969) reported that poult:hen ratios were effective for monitoring production of Rio Grande turkeys in the Texas Panhandle. A power analysis of the Texas data indicated that it had sufficient power to detect a 30% change in poult production given the annual sample sizes of the data (range: 65–306; Schwertner et al. 2003). Second, data were collected in an ad hoc manner during the normal duties of TPWD biologists. Therefore, each observation in each year comes from a potentially different location within each specific ecoregion. As a result, the same populations were not surveyed each year. The data-collection scheme also prevented us from assigning the closest weather station to the survey location. We selected weather stations from around each ecoregion and estimated average conditions in order to capture the cli-

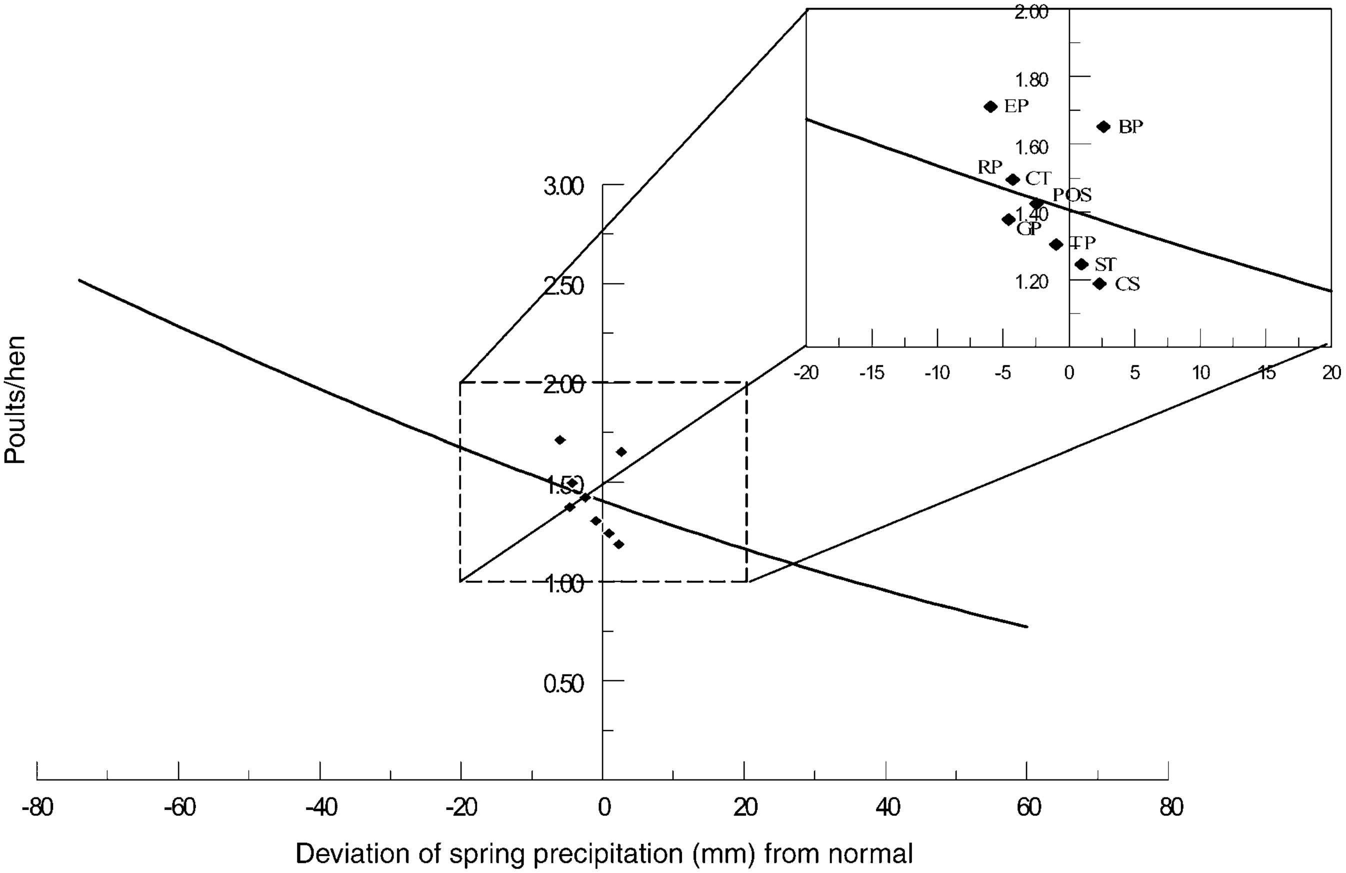

Fig. 2. Rio Grande turkey production (poults/hen) in Texas as a function of the deviation of spring precipitation from the long-term mean. Insets show the predicted poult:hen ratios for each ecoregion based on the long-term ecoregion means. Ecoregion abbreviations are as in Table 2.

mate over the entire ecoregion. This method, however, ignored within-ecoregion climate gradients and dampened weather and climate variation. This could be the reason for the weak performance of the neural models we developed; ecoregion averages were only weakly associated with the poult:hen ratios gathered therein. However, it is not possible for us to definitively say whether given ideal data our models would have explained a higher proportion of the variation in production or if other unmeasured factors exerted stronger control.

DISCUSSION

Our analyses provided preliminary support for the hypothesis that departures from normal conditions help explain annual variation in wild turkey production (Bailey and Rinell 1968); the climate model had the best performance of the models tested. Further research should investigate this conclusion in more detail and test other hypotheses to explain variability in productivity. Similar results have been reported for northern bobwhites in Oklahoma (Lusk et al. 2001) and might indicate that local populations are adapted to local conditions within the genotypic range of the species. Healy (1992:138) concurred with this opinion: "Turkey populations are adapted to the average weather conditions of their region. Weather must deviate substantially from the average—and do so for some time—before it affects populations."

Four variables contributed more than expected to the neural model's predictions. Those variables were the deviation from mean maximum fall temperature, deviation from mean total spring precipitation, deviation from total annual precipitation, and deviation from mean maximum winter temperature. Production declined with annual and spring precipitation above the long-term means. Rain exceeding 380 mm were sufficient to kill poults 12–15 days old, but only at temperatures <8°C over an 18-hour period (Healy and Nenno 1985). Rainfall could be positively related to the ability of nest predators to find and destroy turkey nests (Palmer et al. 1993, Roberts et al. 1995, Roberts and Porter 1998). Predation accounted for 94% of all Rio Grande hen mortalities in Kansas (Hennen and Lutz 2001).

Healy (1992) reported that August through September rainfall was the most important weather-related factor determining wild turkey production, with breeding season rainfall of secondary importance. Our results showed that deviations from spring (breeding season) rainfall had more influence on production than previous fall rainfall (Table 1). Higher Rio Grande turkey productivity in south Texas was thought to be re-

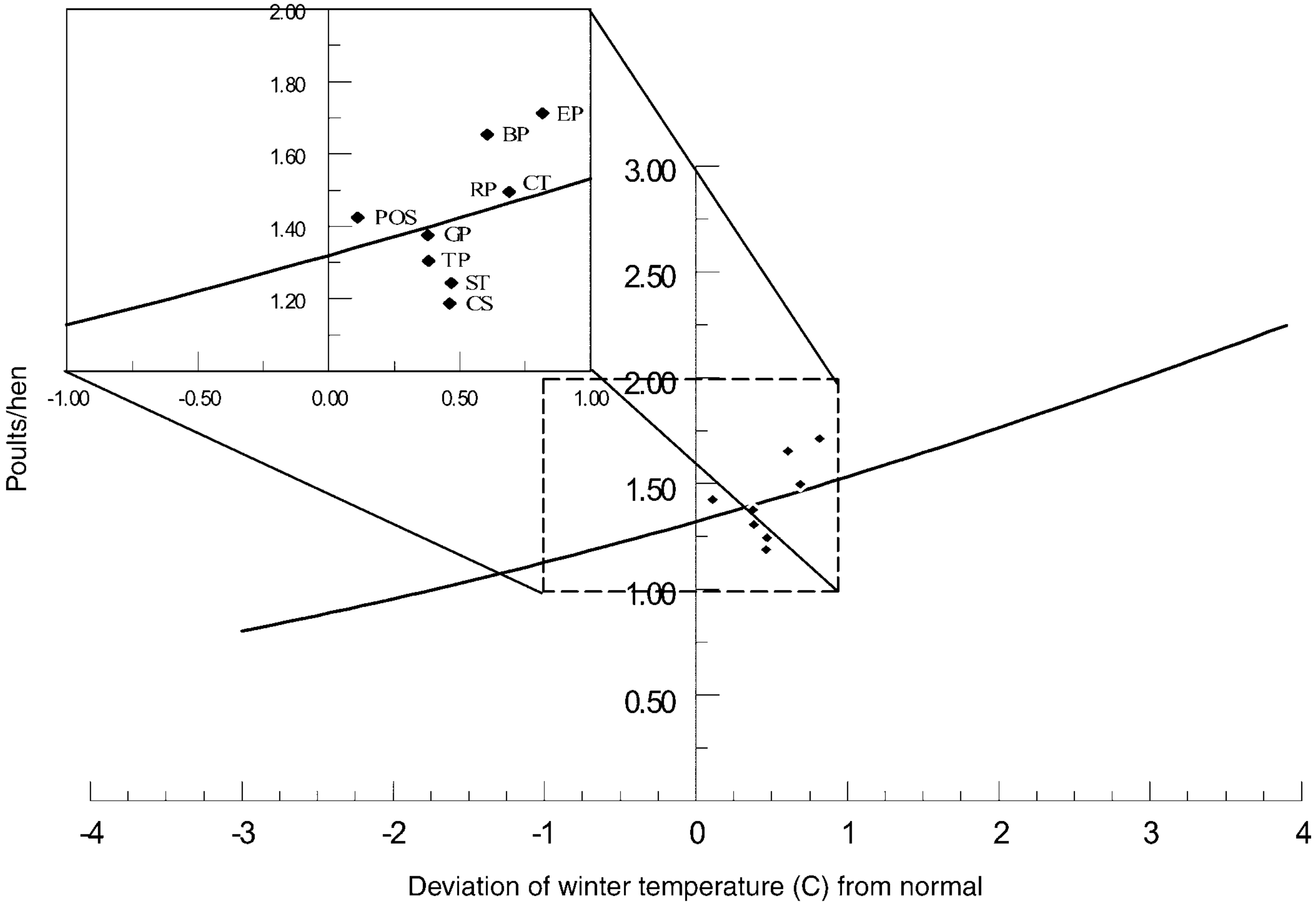

Fig. 3. Rio Grande turkey production (poults/hen) in Texas as a function of the deviation of winter temperature from the long-term mean. Insets show the predicted poult:hen ratios for each ecoregion based on the long-term ecoregion means. Ecoregion abbreviations are as in Table 2.

lated to heavy late summer and early fall rainfall the previous year acting indirectly through vegetation (Baker et al. 1980). Hennen and Lutz (2001) found that low female survival during brood rearing and recruitment seemed to be related to above-average rainfall during the same period. Beasom and Pattee (1980) found that variability in annual Rio Grande turkey productivity was best explained by fall (Sept-Oct) and spring (Mar) rainfall. Although causal mechanisms probably differ among subspecies, breeding season rainfall seems to influence eastern wild turkey production, as well. For example, successful eastern wild turkey nests experienced less cumulative rainfall and fewer rainfall events than did their unsuccessful counterparts (Lowrey et al. 2001).

Temperature has been considered of secondary importance to wild turkey survival and production (Healy 1992). However, our results showed that deviations from long-term mean fall and winter temperatures together had a relevance of 35.1%. Further, the results showed that above-average temperatures in the fall and winter resulted in higher poult:hen ratios the following year. Although Healy (1992) stated that most winter losses were due to starvation rather than the direct effects of temperature, this is not likely the case in Texas where resources are rarely buried under snow cover. However, warmer than average fall and winter temperatures could reduce the energetic demands of overwintering and allow resources to be available for reproduction in the spring. Further, an unusually dry fall could reduce the availability of food resources in the spring exacerbating the effects of a cold winter.

At the ecoregion level in Texas, climate conditions within the Edwards Plateau were best for Rio Grande turkey production. It is, therefore, not surprising that the Edwards Plateau is at the center of the Rio Grande's range in Texas (Beasom and Wilson 1992). Predicted poult:hen ratios were greatest in the Edwards Plateau based on the climate within that region, and production exceeded that predicted from average statewide climate. Ecoregions appeared to fall out along a rainfall gradient, with production declining in increasingly wetter ecoregions (Figure 1, inset), even though in drought years approximately 40% of hens do not lay. The western boundary of the Rio Grande turkey's range occurs where rainfall is insufficient to support trees needed for roosting (Healy 1992).

Future analyses should include catastrophic weather events. A weather catastrophe could be considered to have occurred if ≥1 day within the specified time frame exhibited rainfall events of >380 mm or temperatures <8°C (Healy and Nenno 1985). Such an

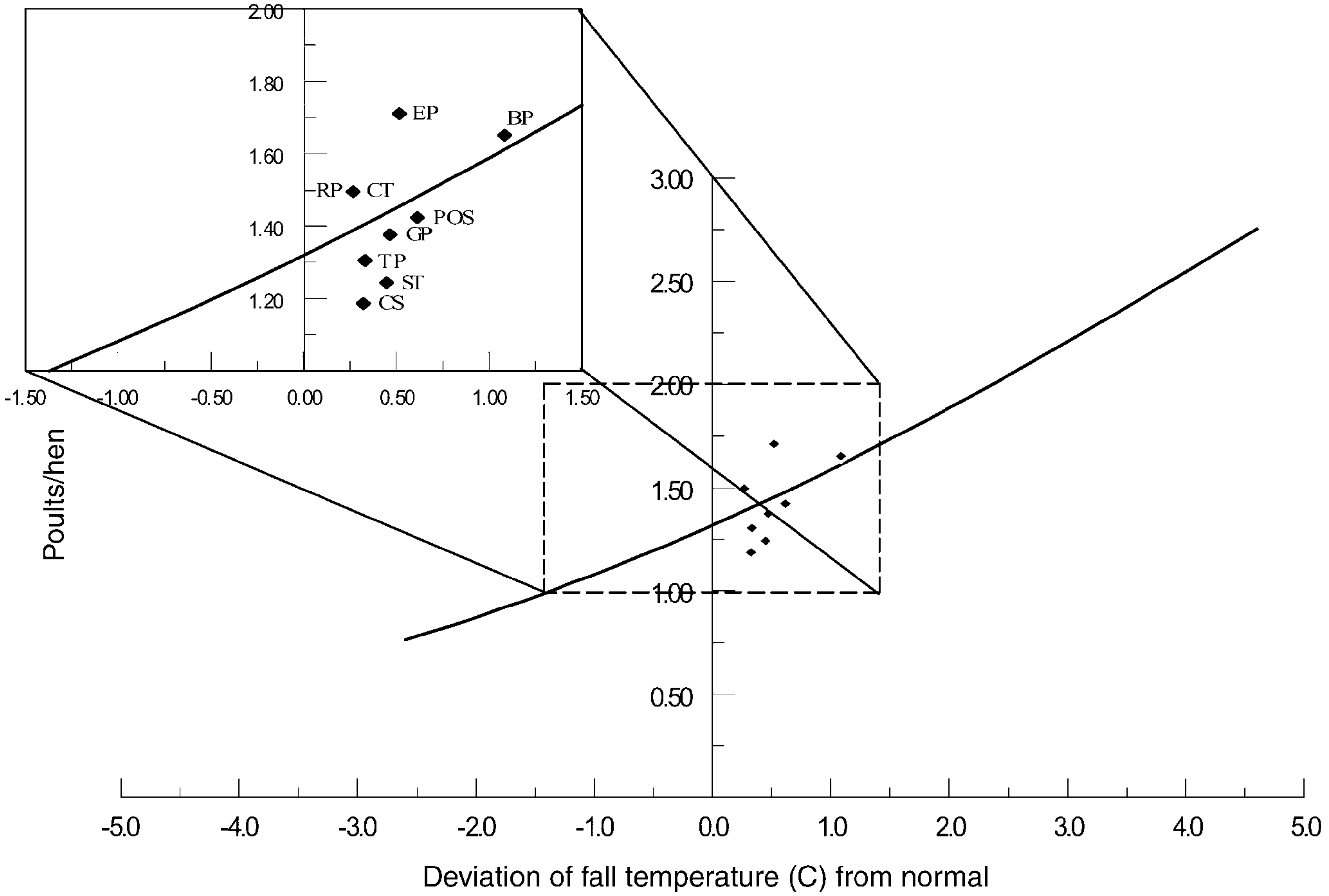

Fig. 4. Rio Grande turkey production (poults/hen) in Texas as a function of the deviation of fall temperature from the long-term mean. Insets show the predicted poult:hen ratios for each ecoregion based on the long-term ecoregion means. Ecoregion abbreviations are as in Table 2.

analysis will allow researchers to test the hypothesis that weather catastrophes predict annual fluctuations in turkey production as suggested by Healy (1992).

MANAGEMENT IMPLICATIONS

Climate and weather are outside the realm of management activities. However, the results presented above provide the environmental context within which management activities must be implemented. As such, it is necessary for managers to understand this environmental context so that more effective management options can be implemented with the aim of maintaining or increasing Rio Grande turkey abundance. The existing repertory of management techniques is still available to managers. However, the implementation of these techniques should consider the overarching climate influences. For example, Beasom and Wilson

Table 2. Predicted poult:hen ratios for Rio Grande turkeys for each ecoregion in Texas based on the average climate conditions of that ecoregion. The average climate conditions (±SE) for the 4 variables that had more than expected influence on the neural model are also provided to aid interpretation of the predicted age ratios. Statewide climate averages predicted 1.43 poults/hen for Texas.

		Deviations from mean . . .			
Ecoregion[a]	Poults/hen	Total annual precipitation (mm)	Total spring precipitation (mm)	Maximum winter temperature (°C)	Maximum fall temperature (°C)
GP	1.38	−21.1 (50.3)	−4.6 (8.1)	0.38 (0.27)	0.47 (0.22)
POS	1.42	−40.1 (48.1)	−2.4 (6.0)	0.11 (0.35)	0.62 (0.24)
BP	1.65	−72.5 (34.2)	2.7 (7.5)	0.61 (0.22)	1.08 (0.18)
CT	1.50	−66.3 (23.7)	−4.3 (3.7)	0.69 (0.33)	0.27 (0.29)
ST	1.24	28.5 (24.8)	1.0 (4.6)	0.47 (0.33)	0.45 (0.20)
EP	1.71	−101.1 (34.5)	−6.0 (4.4)	0.82 (0.29)	0.52 (0.23)
RP	1.50	−66.3 (23.7)	−4.3 (3.7)	0.69 (0.33)	0.27 (0.29)
TP	1.30	−2.6 (25.7)	−0.9 (2.7)	0.38 (0.28)	0.33 (0.21)

[a] Ecoregion codes: GP = Gulf Prairie and Marshes; POS = Post Oak Savannah; BP = Blackland Prairie; CT = Cross Timbers and Prairies; ST = South Texas Plains; EP = Edwards Plateau; RP = Rolling Plains; TP = Trans-Pecos.

(1992) reported that production could be enhanced up to 300% during low-rainfall years using food supplementation. Beasom (1973) reported that in years of higher than normal rainfall, the abundant cover that resulted increased reproductive success up to 700 times compared to dry years when little cover was available. Therefore, if precipitation is expected to be below average, managers might consider steps to improve screening cover for nests as a method of mitigating reduced nest success.

The results reported above also demonstrated the importance of local climate to Rio Grande turkey production. We found that deviations from long-term conditions (i.e., climate) were more important in determining poult:hen ratios than were observed weather patterns, which supports the hypothesis of Bailey and Rinell (1968). Results from our model would seem to imply that Rio Grande turkeys have adapted to local conditions and that production will be increasingly affected as the magnitude of the deviation from normal increases. As a result, managers should consider the local climate conditions when implementing translocations in order to increase the chances of successful establishment.

Climate conditions in the Edwards Plateau were most favorable for Rio Grande turkey production. However, grazing in this ecoregion leads to reductions in nesting cover (Beasom and Wilson 1992) and food availability, especially of important mast species (Blakey 1944). Increased research attention to the effects of grazing on Rio Grande turkeys, therefore, seems warranted.

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LITERATURE CITED

Bailey, R. W., and K. T. Rinell. 1968. History and management of the wild turkey in West Virginia. West Virginia Department of Natural Resources Bulletin 6.

Baker, B. W., S. L. Beasom, and N. J. Silvy. 1980. Turkey productivity and habitat use on South Texas rangelands. Proceedings of the National Wild Turkey Symposium 4:145–158.

Beasom, S. L. 1973. Ecological factors affecting wild turkey reproductive success in south Texas. Dissertation, Texas A&M University, College Station, USA.

———, and O. H. Pattee. 1980. The effect of selected climatic variables on wild turkey productivity. Proceedings of the National Wild Turkey Symposium 4:127–135.

———, and D. Wilson. 1992. Rio Grande turkey. Pages 306–330 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Blakey, H. L. 1944. Welfare of the wild turkey closely associated with range management. Agricultural Experiment Station Progress Report 894, College Station, Texas, USA.

Bridges, A. S., M. J. Peterson, N. J. Silvy, F. E. Smeins, and X. B. Wu. 2001. Differential influence of weather on regional quail abundance in Texas. Journal of Wildlife Management 65:10–18.

DeArment, R. 1969. Turkey hen-poult ratios as an index to reproductive trends. Proceedings of the National Wild Turkey Symposium 1:27–31.

Fielding, A. H. 1999. An introduction to machine learning methods. Pages 1–35 *in* A. H. Fielding, editor. Machine learning methods for ecological application. Kluwer Academic Publishers, Boston, Massachusetts, USA.

Goodman, P. H. 1996. NevProp software. Version 3. University of Nevada, Reno, Nevada, USA.

Gould, F. W. 1975. Texas plants: a checklist and ecological summary. Texas Agricultural Experiment Station, MP-585/Revised, College Station, Texas, USA.

Healy, W. M. 1992. Population influences: environment. Pages 129–143 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

———, and E. S. Nenno. 1985. Effects of weather on wild turkey poult survival. Proceedings of the National Wild Turkey Symposium 5:91–101.

Hennen, R. S., and S. Lutz. 2001. Rio Grande turkey female survival in southcentral Kansas. Proceedings of the National Wild Turkey Symposium 8:117–122.

Hilborn, R., and M. Mangel. 1997. The ecological detective. Princeton University Press, Princeton, New Jersey, USA.

Hohensee, S. D., and M. C. Wallace. 2001. Nesting and survival of Rio Grande turkeys in northcentral Texas. Proceedings of the National Wild Turkey Symposium 8:85–91.

Kurzejeski, E. W., and L. D. Vangilder. 1992. Population management. Pages 165–184 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Lowrey, D. K., S. R. Priest, G. A. Hurst, and B. S. Weemy. 2001. Influences of selected weather variables on predation of wild turkey females and nest success. Proceedings of the National Wild Turkey Symposium 8:173–178.

Lusk, J. J., F. S. Guthery, and S. J. DeMaso. 2001. Northern bobwhite (*Colinus virginianus*) abundance in relation to yearly weather and long-term climate patterns. Ecological Modelling 146:3–13.

———, ———, R. R. George, M. J. Peterson, and S. J. DeMaso. 2002. Relative abundance of bobwhites in relation to weather and land use. Journal of Wildlife Management 66: 1040–1051.

Miller, M. S., D. J. Buford, and R. S. Lutz. 1995. Survival of female Rio Grande turkeys during the reproductive season. Journal of Wildlife Management 59:766–771.

Özesmi, S. L., and U. Özesmi. 1999. An artificial neural network approach to spatial habitat modelling with interspecific interaction. Ecological Modelling 116:15–31.

Palmer, S. R., S. R. Priest, R. S. Seiss, P. S. Phalen, and G. A. Hurst. 1993. Reproductive effort and success in a declining wild turkey population. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 47:138–147.

Roberts, S. D., J. M. Coffey, and W. F. Porter. 1995. Survival and reproduction of wild turkeys in New York. Journal of Wildlife Management 59:437–447.

———, and W. F. Porter. 1998. Relation between weather and survival of wild turkey nests. Journal of Wildlife Management 62:1492–1498.

Schwertner, T. W., M. J. Peterson, N. J. Silvy, and F. E. Smeins. 2003. Brood-count power estimates of Rio Grande turkey production in Texas. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 57:213–221.

Smith, M. 1996. Neural networks for statistical modeling. International Thompson Computer Press, London, United Kingdom.

Wunz, G. A., and W. K. Shope. 1980. Turkey brood survey in Pennsylvania as it relates to harvest. Proceedings of the National Wild Turkey Symposium 4:69–75.

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