Factors Affecting Wild Turkey Recruitment in Western Virginia

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Abstract: Annual recruitment of eastern wild turkeys *(Meleagris gallopavo silvestris)* should be closely monitored to regulate fall turkey seasons and reduce risk of over-harvest. However, previous studies have not encompassed the spatial or temporal scales needed to produce models that can consistently predict recruitment over a large region. Our objective was to assess the ability of using long-term data sets of sex-age ratios, oak (*Quercus* spp.) mast, and weather variables to forecast annual wild turkey recruitment in western Virginia. We conducted a thorough literature search on factors believed to be limiting reproduction and developed a series of 14 *a priori* models and 1 *a posteriori* model to predict recruitment. We used fall harvest ratios of juveniles per adult female, averaged over 26 western Virginia counties, during 1973–2002 as an index to annual recruitment and investigated the relationship of recruitment to age structure of the population, oak mast production in the previous fall, and spring weather. We considered impacts of different weather severity measures and investigated effects of deviation from mean, 90%, and 75% quartile values on recruitment. Our best model ($\omega_9 = 0.812$) predicting recruitment incorporated May and June rainfall and March temperatures at the 75% quartile scale. This model accounted for a significant amount of variation in recruitment residuals ($R^2 = 0.50$, $R^2_{adj} = 0.44$). Monitoring these selected weather parameters offers managers the ability to predict significant changes in recruitment annually.

Key words: acorns, eastern wild turkey, *Meleagris gallapavo silvestris*, oak mast production, precipitation, recruitment, temperature

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Annual recruitment is a critical factor affecting size of wild turkey populations (Roberts et al. 1995, Vangilder and Kurzejeski 1995, Roberts and Porter 1996, Miller et al. 1998). Annual turkey recruitment is affected by several factors, including weather (Healy and Nenno 1985; Vangilder and Kurzejeski 1995; Roberts and Porter 1998a, b), predation (Speake et al. 1985, Peoples et al. 1995), and pre-laying hen condition (Porter et al. 1983, Rowe et al. 1994). Fall–winter food availability may have an important indirect affect on recruitment because of its effect on hen condition (Porter et al. 1983). In areas where turkey habitat is primarily mature forest cover, oak mast (hereafter acorns) provides a critical fall-winter food source. Health and winter survival of turkeys may be reduced in years of poor acorn availability (Steffen et al. 2002).

Several studies have recommended that recruitment be closely monitored to accurately regulate harvest, especially during fall, to reduce risk of overharvest during years of low reproduction (Roberts and Porter 1998a, b; Healy and Powell 1999; Norman et al. 2001). However, administrative and time constraints make it difficult for state wildlife agencies to manipulate fall harvest regulations based on recruitment estimates derived from brood counts or other direct reproduction estimates (Roberts and Porter 1998a, 2001). Intense, targeted studies that closely monitor several reproductive parameters relative to weather and environmental conditions may provide the most detailed information concerning reproduction. Developing accurate estimates of annual recruitment from these data for application to a large area may be limited by time, sample sizes, study scale, and cost. An alternative to these methods is to develop general models based on existing, macro-scale, long-term demographic data and environmental factors (Roberts and Porter 1998a, b, Norman et al. 2001).

Virginia has maintained long-term population demographic data in the form of sex and age ratios from hunter harvest data as well as annual indices of acorn production. These data are often available on a statewide basis, and archived weather data are accessible through the National Climate Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA; Asheville, North Carolina). Our objective was to assess the ability of using these long-term data sets of sex-age ratios, acorn production, and weather variables to forecast annual wild turkey recruitment in western Virginia.

Study Area

We used turkey demographic data, oak mast, and weather variables from 26 counties (8,971 km^2) in the Allegheny Mountain Range of the Ridge and Valley Province of western Virginia. The region was 66% forested, 17% agriculture, and 17% other (urban areas, water, etc.). The primary forest types included oak, oak-hickory (*Carya* spp.), oak-pine (*Pinus* spp.), and yellow poplar *(Liriodendron tulipifera).*

Methods

Recruitment Index

Hunters harvesting a turkey during fall seasons were required to check their turkey at game check stations where breast and wing feathers were collected ($\bar{x}$ = 4,533/yr, range 1,899–6,986). We determined sex and age of harvested turkeys by examining breast feather coloration and primary feather replacement (Pelham and Dickson 1992). We used the ratio of juveniles per adult female in the fall harvest as an index of annual recruitment during the study period 1973–2002. The ratio of juve-

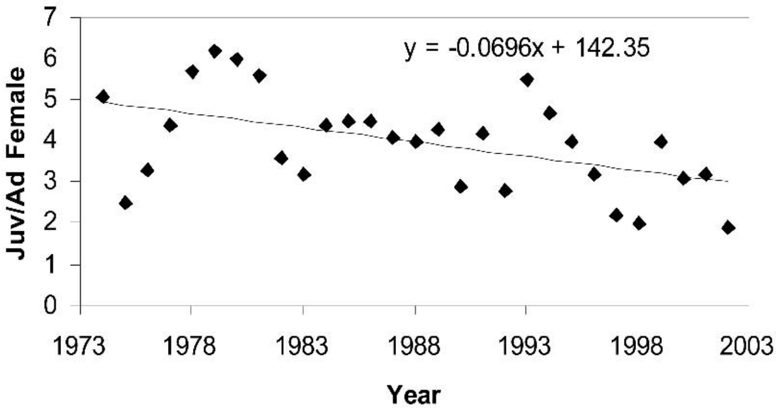

Figure 1. Wild turkey recruitment (juvenile per adult female) from fall hunter-harvested birds 1973–2002 in western Virginia. Annual sample sizes exceeded 1,500 birds. Feather samples (breast and wing) were collected at mandatory big game check stations.

niles per adult female from fall harvested birds may contain some biases. First, we assume that fall harvest rates were similar throughout the study. Pack et al. (1999) reported fall harvest rates of 12% in the study area. Fall season length varied during the study but could be considered long by most standards with either-sex hunting provided for six weeks or longer. Additionally, vulnerability of age and sex classes should remain constant for the index to be unbiased. Hunter preference for adult male turkeys in the spring has been reported in many studies (Healy and Powell 1999); however, little information is available on hunter selectivity of age/sex classes while fall hunting. Annual variation in foods also may affect overall harvest rates and vulnerability of particular age and sex classes. Steffen et al. (2002) found juveniles were equally vulnerable to hunting regardless of food availability, but harvest rates of adult females increased during years of mast failures. Despite these potential sources of variation, we feel these data can be used as an index to recruitment. Because of mandatory checking, annual sample sizes of usable feathers were large. Fall harvests have remained relatively stable with long fall seasons. We believe hunter selection for age/sex groups did not change significantly during the study. Lastly, variation in adult female harvest rates due to mast crops may bias our estimate but this potential bias can be treated by analyzing the data separately based on mast abundance, if needed. Because recruitment has been declining in Virginia during the study period (Fig. 1), we chose to use residual recruitment values as the dependent variable in our research. Residuals represent the deviation from expected linear regression prediction.

Model Building

Based on the literature, we developed *a priori* a series of 14 linear models to explain variability in recruitment residuals. These models incorporated explanatory variables that might impact recruitment including population age structure, hen condition, incubation chronology, nest success, and poult survival. The global model incorporated all potential parameters and was used to initially assess model potential. Models 1–4 attempted to identify importance of hen success versus poult survival. Subsequent models 5–14 added additional parameters to increase model complexity to reflect the suite of environmental factors potentially affecting reproduction (Table1).

Explanatory Factors

Age Structure.—Norman et al. (2001) found that recruitment varied by age classes. Given that annual variation occurs in recruitment, it is likely that significant changes in age structure of the breeding population may effect annual recruitment success in the subsequent year. To evaluate this potential, we investigated recruitment relative to age structure of the population, which we indexed with ratio of juveniles per adult female in the previous fall hunting season.

Hen Condition.—Porter et al. (1983) found severe winter weather affected food resources, hen weights, and reproduction. We used acorn counts from the previous fall as an index to food availability and therefore, physical condition of females. We initiated a system of monitoring acorn production in 1973 based on procedures recommended by Sharp (1958) with some modifications (J. Coggin and C. Perry, Virginia Department of Game and Inland Fisheries, unpub. report). At each site observers counted acorns on the last 61 cm of 10 randomly selected limbs of 80 trees selected from 10 red oak *(Q. rubra)* species group and 10 trees in the white oak *(Q. alba)* species group at 4 different elevations and aspects within the site (low elevations or valleys; medium elevations, southern aspects; medium elevations, northern aspects; and high elevations). We averaged acorn production at the site as total number of acorns from 800 limbs/80 trees. We estimated acorn production by sampling 20 sites throughout western Virginia during 1973–2002. Study area acorn production was the average of the 20 site values.

Incubation Chronology.—Vangilder and Kurzejeski (1995) suggested colder March temperatures delay spring phenology, which may affect the hen's ability to accumulate reserves resulting in delayed nesting, lower nesting and renesting rates, and therefore, lower recruitment. We investigated several weather parameters for March and April including number of days the minimum temperature was ≤0 C and monthly mean minimum temperature. We considered these parameters as an index to winter severity and potentially impacting spring green-up and hen condition. We obtained weather data during 1973–2002 for each of the months of March–June from the NCDC of NOAA. Within each month we averaged each variable across all weather stations (N = 94) within our study area, and we did this for each year of the study.

Table 1. Results of information-theoretic model selection to evaluate competing models explaining recruitment in wild turkeys in Virginia using deviation from mean weather values, 1973–2002. Model 15 was an *a posteriori* model.

Model	N[a]	SSE[b]	K[c]	AIC_c[d]	Δ_I[e]	R^2[f]	R^2_{adj}[g]	ω_I[h]
Model 15: Recruitment = nest success (May rain) + poult survival (Jun rain) + incubation date (Apr days) + ϵ	29	19.09	5	0.48	0.0	0.35	0.27	0.650
Model 1: Recruitment = nest success (May rain) + ϵ	29	27.75	3	5.68	5.2	0.05	0.02	0.048
Model 4: Recruitment = poult survival (May and Jun rain) + ϵ	29	27.73	3	5.66	5.2	0.05	0.02	0.049
Model 11: Recruitment = nest success (May rain) + poult survival (Jun rain) + incubation date (Apr temp) + ϵ	29	23.14	5	6.07	5.6	0.21	0.11	0.040
Model 9: Recruitment = nest success (May rain) + poult survival (Jun rain) + incubation date (Mar temp) + ϵ	29	23.38	5	6.36	5.9	0.20	0.11	0.034
Model 3: Recruitment = poult survival (Jun rain) + ϵ	29	28.64	3	6.60	6.1	0.02	–0.01	0.030
Model 2: Recruitment = nest success (Apr and May rain) + ϵ	29	28.68	3	6.64	6.2	0.02	–0.02	0.029
Model 12: Recruitment = nest success (Apr and May rain) + poult survival (May and Jun rain) + incubation date (Apr temp) + ϵ	29	23.75	5	6.82	6.3	0.19	0.09	0.027
Model 10: Recruitment = nest success (Apr and May rain) + poult survival (May and Jun rain) + incubation date (Mar temp) + ϵ	29	24.45	5	7.66	7.2	0.16	0.06	0.018
Model 5: Recruitment = nest success (May rain) + poult survival (Jun rain) + ϵ	29	27.52	4	8.14	7.7	0.06	–0.01	0.014

Table Continues

Table 1. Continnued

Model	N[a]	SSE[b]	K[c]	AIC_c[d]	Δ_I[e]	R^2[f]	R^2_{adj}[g]	ω_I[h]
Model 6: Recruitment = nest success (Apr and May rain) + poult survival (May and Jun rain) + ϵ	29	27.51	4	8.13	7.7	0.06	–0.01	0.014
Model 8: Recruitment = nest success (Apr and May rain) + poult survival (May and Jun rain) + age structure + ϵ	29	25.01	5	8.32	7.8	0.15	0.04	0.013
Model 7: Recruitment = nest success (May rain) + poult survival (Jun rain) + age structure + ϵ 29	25.08	5	8.39	7.9	0.14	0.04	0.012	
Model 14: Recruitment = nest success (Apr and May rain) + poult survival (May and June rain) + condition (mast) + ϵ	29	25.88	5	9.30	8.8	0.12	0.01	0.008
Global Model: Recruitment = age structure + incubation chronology (Mar and Apr temp) + condition (mast) + nest success (May rain) + poult survival (Jun rain) + time + ϵ	29	15.76	9	9.79	9.3	0.46	0.28	0.006
Model 13: Recruitment = nest success (May rain) + poult survival (Jun rain) + condition (mast) + ϵ	29	26.36	5	9.84	9.4	0.09	–0.01	0.006

a. N = sample size in years

b. SSE = Sum of squares error

c. K = Number of estimable parameters in an approximating model

d. AIC_c = Akaike's Information Criterion adjusted for small sample size

e. Δ_I = Akaike's Information Criterion differences, relative to the smallest AIC value in model set.

f. R^2 = R square

g. R^2_{adj} = Adjusted R square or explanatory power

h. ω_i = Akaike weight. Weights may be interpreted as the probability that the model is actual best model for the sampling situation.

Nest Success.—Predator effectiveness may be increased because of improved scenting conditions when humidity increases in periods of high rainfall. Several research efforts have found a negative relationship between nest success and rainfall (Palmer et al. 1993, Roberts et al. 1995). Peak nest incubation occurs in early May in Virginia (Norman et al. 2001). To examine a potential relationship of rainfall on nest success and ultimately recruitment, we included total May rainfall (peak incubation) and total April and May (early and late incubation) rainfall amounts.

Poult Survival.—Rainfall also can have a significant negative effect on poult mortality, but impact of rains vary with brood age, storm intensity, and minimum temperatures (Healy and Nenno 1985, Healy 1992, Vangilder and Kurzejeski 1995). We investigated the potential of rainfall to impact our recruitment estimates using total rainfall in June (peak hatching), and May and June (early and late hatching) as indices of mortality risks for poults.

Weather Data Scale

Due to the uncertainty of sensitivity or effects of scale of weather measurements, we used three different datasets for each parameter including the (1) deviation from mean, (2) 75% quartile, and (3) 90% quartile as explanatory variables. Bailey and Rinell (1968) suggest that recruitment is affected most by deviation from norms whereas Healy (1992) hypothesized that catastrophic weather events were more significant factors. Although arbitrary, we viewed the 75% and 90% quartile data set as the frequency of "severe" and "catastrophic" weather events, respectively. The 75% and 90% quartile values represented the number of days in the specific period (month, months) that the parameter exceeded either 75% or 90% ranges observed over the 29-year study.

Model Selection

We evaluated models and ranked them using information-theoretic model selection techniques (Burnham and Anderson 2002). We evaluated models within the set based on Akaike's Information Criterion (AIC) adjusted for sample size (AIC_c), AIC_c differences (Δ_i), explanatory power (R^2_{adj}), and Akaike weights (ω_i) (Burnham and Anderson 2002). We considered models of $\leq$4 ΔAIC units to be competing models. Akaike weight (ω_i) estimates the probability that a particular model is the best model in the candidate set (Burnham and Anderson 2002).

Results

Our initial investigations using deviation from mean weather parameters suggested Model 11 was the best model (Table 1). Therefore, we developed an *a posteriori* model (Model 15) by substituting number of days April temperatures were $\leq$0 C for April mean minimum temperature to explore the value of another measure of April temperatures. Model 15 performed better than any other *a priori* models using weather parameters based on deviation from mean (Table 1). Parameters in Model 15 included nest success (May total rain) + poult survival (Jun total rain) + incubation date (Apr days $\leq$0 C).

Models 11 and 12 performed better than any other models using 90% quartile (catastrophic) weather data (Table 2). However, there was a large amount of model uncertainty in the 90% quartile set given the low model weights (highest $\omega_I = 0.49$).

Model 9 from the 75% quartile (severe) weather data was clearly the best model ($\omega_I = 0.81$) and this model accounted for a significant amount of variation ($R^2_{adj} = 0.44$) in recruitment residuals (Table 3). Model 9 incorporated nest success (days May rain) + poult survival (days Jun rain) + incubation date (days Mar minimum temperature). The linear regression equation for Model 9 was recruitment residual = 0.177 – 0.294 (days May rain ≥ 75% quartile) + 0.079 (days Jun rain ≥ 75% quartile) + 0.193 (days Mar minimum temperature ≥ 75% quartile). Model 9 coefficients suggest higher recruitment can be expected with warmer March temperatures, fewer severe May rainfall days, and more severe June rainfall days.

Discussion

Our best model incorporated three of five parameters we identified from the literature as potential factors limiting turkey reproduction. As expected, the selected parameters included a positive relationship between recruitment residuals and March minimum temperatures (nest incubation date) and a negative relationship between recruitment residuals and May rainfall (nest success).

Vangilder and Kurzejeski (1995) suggest spring phenology may be delayed by colder March temperatures, which in turn may affect a hen's pre-laying energy reserves, delay nesting, and lower nest success. Rowe et al. (1994) also found a correlation between poor female condition and delayed incubation dates. Seiss et al. (1990) suggested early nesting hens may lack adequate ground cover and may therefore be more exposed to predators and disturbances. In Virginia, Norman et al. (2001) found incubation initiation typically occurs in early May, and variation in initiation time was correlated with March temperatures. Although they failed to detect a direct relationship between March temperatures and their reproductive parameters, they did find that hens with delayed incubation dates had lower incubation completion rates (Norman et al. 2001). Our ability to detect an influence of March temperatures on recruitment in this study may have been due in part to greater variation in recruitment in our longer study period (29 years) compared to the limited period (5 years) Norman et al. (2001) studied radio-marked females.

May rainfall exhibited a negative relationship to recruitment residuals in our study. Studies conducted in Mississippi (Palmer et al. 1993) and New York (Roberts et al. 1995) hypothesized that periods of high rainfall during hen incubation increased predator effectiveness in locating incubating hens, resulting in lower nest success. In Mississippi, Lowery et al. (2001) found that higher rainfall occurred at unsuccessful nest sites, and annual nest success was negatively correlated with the total number of rainfall events.

June rainfall also was a significant parameter estimator in our model; however, the relationship was unexpectedly positive. Many research efforts have supported a negative relationship between poult survival and rainfall (Roberts and Porter 1998b, Vangilder and Kurzejeski 1995). However, Healy (1992:138) points out that rain is

Table 2. Results of information-theoretic model selection to evaluate competing models explaining recruitment in wild turkeys in Virginia using 90% quartile weather values, 1973–2002. Model 15 was an *a posteriori* model. The 90% quartile values represented the number of days in the specific period (month, months) that the parameter exceeded the 90% quartile range observed over the 29-year study.

Model	N^a	SSE[b]	K^c	$AIC_c{}^d$	$\Delta_I{}^e$	R^{2f}	$R^2_{adj}{}^g$	$\omega_I{}^h$
Model 11: Recruitment = nest success (May rain) + poult survival (Jun rain) + incubation date (Apr temp)	29	15.24	5	–6.04	0.0	0.48	0.42	0.493
Model 12: Recruitment = nest success (Apr and May rain) + poult survival (May and Jun rain) + incubation date (Apr temp) + ϵ	29	15.39	5	–5.76	0.3	0.47	0.41	0.427
Model 15: Recruitment = nest success (May rain) + poult survival (Jun rain) + incubation date (Apr days) + ϵ	29	15.76	5	–1.87	4.2	0.60	0.46	0.061
Global Model: Recruitment = age structure + incubation chronology (Mar and Apr temp) + condition (mast) + nest success (May rain) + poult survival (Jun rain) + time + ϵ	29	11.59	9	0.88	6.9	0.60	0.47	0.015
Model 2: Recruitment = nest success (Apr and May rain) + ϵ	29	28.82	3	6.77	12.8	0.02	–0.02	<0.001
Model 1: Recruitment = nest success (May rain) + ϵ	29	29.12	3	7.15	13.2	0.03	–0.02	<0.001
Model 4: Recruitment = poult survival (May and Jun rain) + ϵ	29	29.18	3	7.14	13.2	0.00	–0.03	<0.001
Model 3: Recruitment = poult survival (Jun rain) + ϵ	29	29.22	3	7.18	13.2	0.00	–0.04	<0.001
Model 6: Recruitment = nest success (Apr and May rain) + poult survival (May and Jun rain) + ϵ	29	28.81	4	9.48	15.5	0.02	–0.06	<0.001

Table Continues

Table 2. Continued

Model	N[a]	SSE[b]	K[c]	AIC_c[d]	Δ_I[e]	R^2[f]	R^2_{adj}[g]	ω_I[h]
Model 5: Recruitment = nest success (May rain) + poult survival (Jun rain) + ϵ	29	29.17	4	9.84	15.9	0.00	–0.07	<0.001
Model 8: Recruitment = nest success (Apr and May rain) + poult survival (May and Jun rain) + age structure + ϵ	29	26.44	5	9.94	16.0	0.10	–0.01	<0.001
Model 7: Recruitment = nest success (May rain) + poult survival (Jun rain) + age structure + ϵ	29	26.85	5	10.37	16.4	0.08	–0.03	<0.001
Model 14: Recruitment = nest success (Apr and May rain) + poult survival (May and June rain) + condition (mast) + ϵ	29	27.99	5	11.58	17.6	0.04	–0.07	<0.001
Model 13: Recruitment = nest success (May rain) + poult survival (Jun rain) + condition (mast) + ϵ	29	28.08	5	11.67	17.7	0.04	–0.07	<0.001
Model 10: Recruitment = nest success (Apr and May rain) + poult survival (May and Jun rain) + incubation date (Mar temp) + ϵ	29	28.24	5	11.84	17.9	0.04	–0.08	<0.001
Model 9: Recruitment = nest success (May rain) + poult survival (Jun rain) + incubation date (Mar temp) + ϵ	29	28.40	5	12.0	18.1	0.03	–0.09	<0.001

a. N = sample size in years
b. SSE = Sum of squares error
c. K = Number of estimable parameters in an approximating model
d. AIC_c = Akaike's Information Criterion adjusted for small sample size
e. Δ_I = Akaike's Information Criterion differences, relative to the smallest AIC value in model set.
f. R^2 = R square
g. R^2_{adj} = Adjusted R square or explanatory power

Table 3. Results of information-theoretic model selection to evaluate competing models explaining recruitment in wild turkeys in Virginia using 75% quartile weather values, 1973–2002. Model 15 was an *a posteriori* model. The 75% quartile values represented the number of days in the specific period (month, months) that the parameter exceeded either 75% quartile range observed over the 29-year study.

Model	N[a]	SSE[b]	K[c]	AIC_c[d]	Δ_I[e]	R^2[f]	R^2_{adj}[g]	ω_I[h]
Model 9: Recruitment = nest success (May rain) + poult survival (Jun rain) + incubation date (Mar temp) + ϵ	29	14.74	5	–7.01	0.00	0.50	0.44	0.812
Model 11: Recruitment = nest success (May rain) + poult survival (Jun rain) + incubation date (Apr temp) + ϵ	29	17.35	5	–2.28	4.73	0.41	0.34	0.076
Model 15: Recruitment = nest success (May rain) + poult survival (Jun rain) + incubation date (Apr days) + ϵ	29	15.72	5	–1.93	5.08	0.46	0.40	0.064
Model 1: Recruitment = nest success (May rain) + ϵ	29	22.92	3	0.14	7.15	0.22	0.19	0.023
Model 5: Recruitment = nest success (May rain) + poult survival (Jun rain) + ϵ	29	22.83	4	2.73	9.74	0.22	0.16	0.006
Model 7: Recruitment = nest success (May rain) + poult survival (Jun rain) + age structure + ϵ	29	20.90	5	3.11	10.12	0.29	0.20	0.005
Model 12: Recruitment = nest success (Apr and May rain) + poult survival (May and Jun rain) + incubation date (Apr temp) + ϵ	29	21.59	5	4.05	11.06	0.26	0.17	0.003
Model 4: Recruitment = poult survival (May and Jun rain) + ϵ	29	26.64	3	4.50	11.51	0.09	0.06	0.003
Model 13: Recruitment = nest success (May rain) + poult survival (Jun rain) + condition (mast) + ϵ	29	22.33	5	5.03	12.04	0.23	0.15	0.002

Table Continues

Table 3. Continued

Model	N[a]	SSE[b]	K[c]	AIC_c[d]	Δ_I[e]	R^2[f]	R^2_{adj}[g]	ω_I[h]
Model 10: Recruitment = nest success (Apr and May rain) + poult survival (May and Jun rain) + incubation date (Mar temp) + ϵ	29	23.19	5	6.13	13.14	0.21	0.11	0.001
Model 6: Recruitment = nest success (Apr and May rain) + poult survival (May and Jun rain) + ϵ	29	26.33	4	6.86	13.87	0.10	0.03	<0.001
Model 2: Recruitment = nest success (Apr and May rain) + ϵ	29	28.03	3	5.97	13.99	0.04	0.01	0.001
Model 3: Recruitment = poult survival (Jun rain) + ϵ	29	29.12	3	7.08	14.09	0.01	–0.03	<0.001
Model 8: Recruitment = nest success (Apr and May rain) + poult survival (May and Jun rain) + age structure + ϵ	29	24.17	5	7.33	14.34	0.17	0.08	<0.001
Model 14: Recruitment = nest success (Apr and May rain) + poult survival (May and June rain) + condition (mast) + ϵ	29	24.88	5	8.17	15.18	0.15	0.05	<0.001
Global Model: Recruitment = age structure + incubation chronology (Mar and Apr temp) + condition (mast) + nest success (May rain) + poult survival (Jun rain) + time + ϵ	29	15.89	9	10.03	17.04	0.46	0.28	<0.001

a. N = sample size in years
b. SSE = Sum of squares error
c. K = Number of estimable parameters in an approximating model
d. AIC_c = Akaike's Information Criterion adjusted for small sample size
e. Δ_I = Akaike's Information Criterion differences, relative to the smallest AIC value in model set.
f. R^2 = R square
g. R^2_{adj} = Adjusted R square or explanatory power

only problematic when associated with low temperatures (7–11 C). Norman et al. (2001) also failed to find a relationship between June rainfall and poult survival.

These counter-intuitive results could support the notion that effects of June rainfall were positive because of beneficial effects of rain on brood habitat quality and insect production. This type of relationship has been found in more arid sections of wild turkey range, notably in South Texas (Beasom 1973). Beasom (1973) found that survival of poults was not affected by rainfall but drought conditions negatively affected habitat quality and reproduction.

We found no relationship between population age structure and recruitment residuals. Norman et al. (2001) found reproduction varied by age and we therefore expected to see some effects of high reproduction years in the sequent recruitment residuals. We did not examine a longer lag effect (i.e., 3 yr), which potentially could have greater impacts given results of higher reproductive success of older (3-yr-old) hens (Norman et al. 2001).

We found no apparent influence of acorn production on recruitment residuals. Acorn production can affect health and winter survival of wild turkeys (Vangilder 1996, Steffen et al. 2002), but the impact of a poor acorn crop on the pre-nesting condition of the hen may be confounded by other factors, such as winter and early spring temperatures and precipitation (Vangilder and Kurzejeski 1995, Norman et al. 2001). These factors also may have diminished the effect of oak mast on recruitment in our study. Additionally, effects of severe winter weather and reduced food resources on reproduction that Porter et al. (1983) found in Minnesota were likely more severe than the milder Virginia climate we studied. Because acorn production tends to be similar across the state within a given year (Fearer et al. 2002), we do not feel that the large spatial scale of our study contributed to our inability to detect an effect of acorn production on recruitment.

Turkey recruitment is clearly a complex, multivariate process involving many environmental influences. Our attempts to simplify the process were moderately successful as we were able to account for a significant amount of variation in the Virginia recruitment data. Further improvements in the model may come from combining some weather parameters, specifically rainfall and temperature in June. However, these refined data sets were not readily available through common weather services. While weather plays an important role in recruitment processes, predation rates (Speake et al. 1985, Palmer et al. 1993) also are a critical influence as well. Incorporation of predator abundance estimates also may improve model predictions.

We examined weather patterns on three scales, deviation from mean, and 75% and 90% quartiles. The 75% quartile value was selected to represent occurrence of severe events and the 90% quartile was selected to represent the number of catastrophic weather events. The basis of this approach was justified to investigate the two prevailing hypotheses concerning weather impacts on reproduction. The first suggests that production decreases as average temperature and rainfall deviate from normal (Bailey and Rinell 1968) and the second that catastrophic weather events best explain variability in production (Healy 1992). Our modeling work suggests that the 75% quartile data set best explained variation in recruitment in Virginia. This tends to support Healy's hypothesis, but it is important to note that the model fit declined with higher levels of catastrophic events (90%). Our selection of 75% and 90% quartile values was arbitrary and further research may identify the different levels of severe or catastrophic weather events to further improve model predictions.

Because our recruitment estimate (ratio of juveniles per adult female in the fall harvest) was an index and not a direct measure of recruitment, we may have missed some effect of weather or other parameters (i.e., mast) on recruitment. Other annual recruitment indices (i.e., brood counts) may reflect the effects of weather on recruitment more accurately. The large spatial scale at which we conducted our analyses also may have negated the effect of more localized variations in weather on recruitment, and smaller scales, such as ecological or state-defined administrative regions, may be more appropriate for detecting the effects of weather on recruitment.

Management Implications

We feel the relationships between weather and recruitment demonstrated in our modeling process were valid, and use of long-term, macro-scale weather data sets to model recruitment over a large area warrants further investigation. Models using these long-term and macro-scale data can provide cost-effective and efficient methods for predicting annual recruitment changes and modeling population trends that can help managers with public relations and harvest management decisions.

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