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THE TEXAS QUAIL INDEX: EVALUATING PREDICTORS OF NORTHERN BOBWHITE PRODUCTIVITY AND ABUNDANCE USING CITIZEN SCIENCE

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ABSTRACT

Annual abundance of northern bobwhites (*Colinus virginianus*) fluctuates drastically in semi-arid environments (e.g., Texas), which complicates the ability of wildlife biologists and quail managers to predict annual bobwhite productivity and relative abundance for the ensuing hunting season. The Texas Quail Index (TQI) was a 5-year citizen science project that evaluated several indices as predictors of bobwhite productivity and abundance during the subsequent fall. Indices included spring cock-call counts, forb species richness, simulated-nest fate, potential nest-site density, scent station visitation rates, roadside counts, fall covey call counts, and harvest data. Spring cock-call counts explained only 41% of the variation in fall bobwhite abundance across all study sites in years 1–4; yet explained 89% of the variation in year 5. The percentage of juveniles in the fall population (an index of bobwhite productivity) was significantly lower in year 5. All study sites experienced drought conditions throughout year 5 based on the Palmer Drought Severity Index (PDSI). Thus, drought conditions in semi-arid environments result in reduced productivity compared to non-drought years. Our results suggest low recruitment during drought years makes fall bobwhite abundance more predictable than during non-drought years. Wildlife biologists and quail managers should have a better ability to predict bobwhite productivity and fall abundance in drought years by recording spring cock-call counts.

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Key words: call counts, citizen science, *Colinus virginianus*, density estimate, northern bobwhite, population dynamics, predators, quail abundance, reproduction, Texas

INTRODUCTION

Annual abundance of northern bobwhites fluctuates drastically in Texas (Lehmann 1984:124, Peterson 2001), particularly in semiarid regions (Bridges et al. 2001, Lusk et al. 2005). The exact mechanism(s) governing these fluctuations is still unclear (Hernández and Peterson 2007), although weather accounts for much of this variation in bobwhite populations (Bridges et al. 2001, Lusk et al. 2005). Quail managers in these regions lease trespass-rights to quail hunters dependent upon quail abundance. Drastic population fluctuations complicate forecasting, scheduling, and overall harvest management. Thus, quail managers need a practical and reliable method to forecast quail abundance on their property well before ($\geq$ 6 months) the hunting season.

The Texas Quail Index (TQI) was a 5-year (2002–2006) citizen science project that assessed the relationship between indices of quail abundance, habitat conditions, and bobwhite abundance during the following quail hunting season. Indices included spring cock-call counts, forb species richness, simulated-nest fate, potential nest-site density, scent station visitation rates, roadside counts, fall covey call counts, and harvest data.

Previous studies evaluated the forecasting efficacy of a variety of indices of quail abundance, including spring cock-call counts (Bennitt 1951, Reeves 1954, Rosene 1957, Brown et al. 1978), roadside counts (Peterson and Perez 2000), and fall covey-call counts (Roseberry and Klimstra 1984, Guthery 1986:138–141, DeMaso et al. 1992). Spring cock-call counts are an inexpensive way to index quail populations over an extensive area and are good indicators of breeding potential (Hansen and Guthery 2001, Rollins et al. 2005), but results differ as to whether spring cock-call counts are effective predictors of quail abundance for the following hunting season (Rosene 1957, Norton et al. 1961, Ellis et al. 1972, Snyder 1984). Fall covey-calls of bobwhites are thought to

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primarily function to announce a covey's location to neighboring coveys (Wellendorf and Palmer 2004). Stoddard (1931), Roseberry and Klimstra (1984), and DeMaso et al. (1992) used fall covey-call counts to index fall quail abundance and spatial distribution. These indices have been criticized as measures of abundance (Norton et al. 1961, Anderson 2001), but may enable detection of relative differences in populations among areas or years (Guthery 2000:103, Engeman 2003).

Forb species richness indicates the diversity of forbs that produce seeds and host insects that are consumed by quail (Stoddard 1931), and which are vital for chick survival (Guthery 2000). Bobwhites typically nest in a bunchgrass about 0.4 m in diameter (e.g., little bluestem [*Schizachyrium scoparium*]), or a clump of prickly pear (*Opuntia* spp.) about 1.0 m in diameter (Hernández et al. 2001, Slater et al. 2001), and we recorded the density of potential nesting sites.

Reliable estimates of the abundance of most carnivores, due to their elusiveness, are difficult and expensive to obtain (Sargeant et al. 2003). Thus, biologists may rely on indices of relative abundance (i.e., scent-station visitation rates; Travaini et al. 1996, Warrick and Harris 2001) with varying success (Conner et al. 1983, Minser 1984, Nottingham et al. 1989, Diefenbach et al. 1994, Sargeant et al. 2003). Simulated quail-nest fate also provides an index of actual bobwhite nest success (% nests intact) relative to habitat condition and predator activity (Hernández et al. 2001, Slater et al. 2001, Buntyn 2004).

The ratio of juveniles to adults in the fall harvest is often used as an index of production (Stoddard 1931, Pollock et. al 1989, Roseberry and Klimstra 1992, Flanders-Wanner et al. 2004). However, age ratios can be misleading as they reflect relative survival of adults, as well as their productivity (Guthery 2000), and the differential vulnerability of adults and juveniles to harvest (Pollock et. al. 1989, Shupe et al. 1990, Roseberry and Klimstra 1992). As a result, Guthery (2000) recommended using an index of quail population density (e.g., hunting success rates) in conjunction with age ratios.

The TQI used citizen scientists (i.e., trained volunteers) to record all indices for 3 reasons: (1) citizen science is practical and affordable in projects where collection of data is large-scale, time-sensitive, and funding is limited (Altizer et al. 2004); (2) it has been used increasingly for survey and monitoring animal populations (Lepczyk 2005); and (3) it is a tool to educate the public about science while collecting useful data (Brossard et al. 2005). Our objectives were to: (1) identify which (if any) indices were good predictors of fall abundance of bobwhites, and (2) inform landowners, ranch managers, and local land support personnel (i.e., state biologists or county extension agents) on ways to assess their quail populations, while collecting useful data.

STUDY AREA

Study sites were in 59 Texas counties (Fig. 1), including 65 private ranches and 6 Wildlife Management Areas, in 5 ecological regions of Texas (Gould 1975). Twenty-three counties were in the Rolling Plains, 13 in the Edwards Plateau, 11 in the Cross Timbers and Prairies, 10 in the South Texas Plains, and 2 in the Trans-Pecos ecoregions.

METHODS

Cooperator Recruitment and Training

We mailed invitations to participate in the TQI to county Texas AgriLife Extension agents, agency biologists (e.g., Texas Parks and Wildlife Department), and private landowners in Texas. New cooperators attended a 2-day training session in April each year. This included classroom instruction, field training, and testing to ensure cooperators were capable of conducting each survey on their respective sites. Each cooperator also received a packet including detailed instructions and materials necessary to follow TQI protocols. A web site (teamquail.tamu.edu) provided appropriate literature and data sheets for cooperators including contact information for the TQI coordinator—the primary point of contact.

Establishing Permanent Transects

Each cooperator established a 16-km, road-based permanent transect on their property with data collection points (i.e., numbered signs attached to steel t-posts) established at 1.6-km intervals (Bennitt 1951, Brown et al. 1978). Transects along existing ranch roads, at times, were not straight, but were chosen to minimize overlap of the presumed 600-m radius of audibility for bobwhites (Rollins et al. 2005) between data collection point locations. Cooperators selected a transect location sufficiently removed from heavily-traveled roads that was representative of the habitat types on the property. Each cooperator recorded their transect on a map for approval by the TQI coordinator.

Potential Indices of Bobwhite Abundance

We selected 5 indices of bobwhite abundance to be monitored by cooperators: spring cock-call counts, forb species richness, simulated-nest fate, potential nest-site density, and scent station visitation rates.

Spring Cock-call Counts.—Cooperators counted the number of calling males heard at each data collection point ($n = 11$) and recorded the approximate location (distance and direction from the collection point) of each male detected (Guthery 1986, Rollins et al. 2005) during a 5-min span (Reeves 1954, Rosene 1957, Hansen and Guthery 2001), at, or just prior to official sunrise (Bennitt 1951, Norton et al. 1961, Hansen and Guthery 2001). All counts were to be completed within $\sim$ 1.5 hrs. Counts were replicated 3 or 4 times (Smith and Gallizioli 1965) between 1 May and 1 June, and were not conducted during rain or when winds exceeded 16 km/hr. Cooperators reported the average number of calling bobwhites/stop as the spring cock-call index.

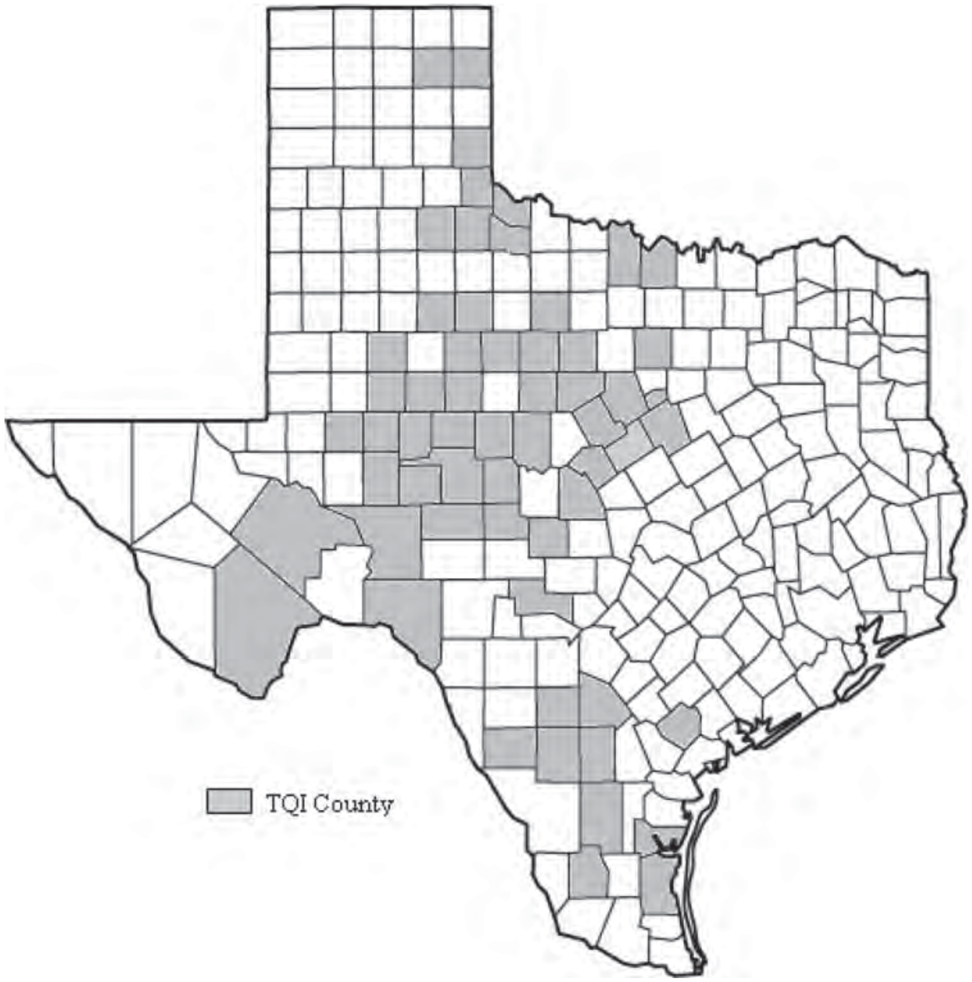

Fig. 1. Distribution of Texas Quail Index study sites by county, 2002–2006.

Forb-species Richness.—Cooperators recorded forb species richness by tossing a 1-m diameter circular quadrat over their shoulder at each collection point. The ultimate location of the circular quadrat served as a random sampling point. Cooperators recorded the number of different forb species rooted within the quadrat, and recorded the average for all points as the forb diversity index.

Simulated-nest Fate.—A 300-m nesting transect was established perpendicular to the permanent transect at 6 randomly selected data collection points. Cooperators established a simulated nest at 50-m intervals in a suitable nesting substrate, typically a bunchgrass about 0.5 m in diameter (e.g., little bluestem), or a clump of prickly pear about 1.0 m in diameter (Hernández et al. 2001, Slater et al. 2001). Cooperators recorded the coordinates of the nest for ease of relocation. Cooperators placed 3 domestic chicken eggs and a steel washer (2.0-cm diameter) in each nest. The steel washer increased the probability of finding the nest bowl when eggs were missing. Cooperators replaced eggs in non-disturbed nests after 14 days and wore latex gloves while handling eggs to reduce human scent (Whelan et al. 1994). Cooperators recorded fate of simulated nests as intact or depredated at 14 and 28 days after establishment (spanning the 23-day incubation period of bobwhites; Stoddard 1931). Nests were considered depredated if $\geq$ 1 egg was rolled out of the nest bowl or destroyed. The percentage of nests intact after 14 days of exposure was the simulated-nest index.

Potential Nest Sites.—Cooperators, after establishing simulated-nests, walked back to the data collection point (300 m from the last simulated-nest) holding their arms out straight at shoulder height, perpendicular to their body and recorded the number of potential nests sites (i.e., suitable nesting substrates) rooted within their arms' span ($\sim$ 2 m for a person 2 m in height; Rollins et al. 2005). The density of potential nest sites was reported as the potential nest site index.

Scent-station Visitations.—The TQI scent-station protocol followed Linhart and Knowlton's (1975) general methodology and incorporated Roughton and Sweeny's (1982) recommended modifications. Cooperators removed all vegetation and debris from a circular area 1-m in diameter and covered the area with a smooth layer of tracking substrate (i.e., flour), at each data collection point in May. Flour enabled detection of visitation to a scent lure (fatty acid scent tablet; Pocatello Supply Depot, Pocatello, ID, USA) placed in the center of the station.

Table 1. Stepwise multiple regression data for the Texas Quail Index. Transformed fall covey-call counts ($FC_t = \ln$ [fall covey-call counts + 1]) were used as the dependent variable.

Independent variable	Standardized coefficient	Significance
Spring cock-call counts	0.675	<0.001
Habitat photo points	0.157	0.301
Forb species richness	−0.200	0.187
Simulated-nest fate	0.147	0.338
Predator scent-stations	0.085	0.586
Potential nest sites	−0.004	0.981

The following morning, cooperators recorded the presence or absence of tracks of individual carnivore species. Cooperators repeated the process for 2 consecutive nights replenishing flour and lure as needed for day 2. The average of the 2 nights comprised the predator scent-station index (mean number of visits/100 scent-station nights [SSN]). Precipitation, wind, or non-target animals (e.g., livestock) occasionally obliterated stations; these occurrences were censored in the analysis.

Measures of Bobwhite Abundance

We selected 3 indices of bobwhite abundance during the fall to be recorded by cooperators: (1) roadside counts, (2) fall covey-call counts, and (3) harvest data.

Roadside Counts.—Cooperators recorded the number of bobwhites visually observed as they drove transects at $\leq$ 33.3 km/hr within 1.5 hrs of either dawn or dusk on 3 different days during the first 2 weeks of September (Peterson and Perez 2000). The direction of travel along transects alternated between successive counts. The average of all counts comprised the roadside count index.

Fall Covey-call Counts.—Fall covey-call counts were conducted at 1 data collection point per morning because fall covey-calls are elicited for < 20 min during the early morning. Counts began ~ 40 min before official sunrise (typical covey calling time; Rosene 1957). Cooperators recorded the number of coveys calling and the approximate location (distance and direction from the data collection point) of each covey calling. Call counts were not conducted during rain or when winds exceeded 16 km/hr. Cooperators repeated fall covey-call counts at 2 to 4 randomly selected data collection points between 1 October and 15 November (Wellendorf and Palmer 2004). The average of all counts was the fall covey-call index (number of coveys calling/stop).

Harvest Data.—Cooperators recorded 2 harvest variables during quail hunts from November to February: (1) number of coveys flushed per hour of hunting effort (an index of density), and (2) percentage of juveniles in the hunter's bag. Cooperators recorded age of bobwhites from an examination of the primary coverts (Stoddard 1931, Guthery 2000).

Statistical Analyses

We used the Statistical Package for the Social Sciences (SPSS; Chicago, IL, USA) Version 15.0 to analyze data from each study site. An observation consisted of 1 year of data per study site. We evaluated 6 spring and summer indices as predictors of hunting-season bobwhite abundance using multiple regression analysis with stepwise inclusion of variables (Ott and Longnecker 2001).

The candidate independent variables were spring cock-call counts (SC), forb species-richness (FD), simulated-nest fate (SN), predator scent-stations (PS), and potential nest sites (PN). Dependent variables were the number of coveys flushed/hour of hunting effort (CF), roadside counts (RC), and fall-covey counts (FC). We used fall-covey counts as the dependent variable for our analysis due to the variation of roadside counts (coefficient of variation = 1.30) and the low sample size of cooperators that recorded the number of coveys flushed per hour of hunting effort ($n = 5$). Fall-covey counts were strongly correlated with coveys flushed per hour of hunting effort on sites where recorded ($r = 0.81$).

We transformed fall covey counts to achieve normality ($P = 0.2$) as ($FC_t = \ln$ [FC + 1]). A Breusch-Pagan (1979) test indicated that FC_t met constant variance assumptions ($P = 0.29$, α-level = 0.01). All tests used an *alpha*-level of 0.05 to denote statistical significance unless otherwise stated. We used FC_t as the dependent variable for an initial regression equation of

$$FC_t = \beta_0 + \beta_1(SC) + \beta_2(FD) + \beta_3(SN) + \beta_4(PS) + \beta_5(PN) + \varepsilon,$$

where β_o is the intercept, β_1–β_6 are slopes of the corresponding indices, and ε is error. An *alpha*-level of 0.05 was used for inclusion of variables and 0.10 for removal of variables. We used analysis of covariance (Ott and Longnecker 2001) to test for variation among years and ecological regions. The test equation was

$$FC_t = \beta_{0i} + \beta_{1i}(SC) + \varepsilon,$$

where $i = 1$–5 for years 2002–2006 respectively, or $i = 1$–4 for ecoregions (1 = Rolling Plains, 2 = Edwards Plateau, 3 = Cross Timbers, 4 = South Texas Plains). We used a Fisher's least significant difference (LSD) procedure (Ott and Longnecker 2001) to examine which year(s) explained more of the variation in FC_t.

RESULTS

Data Collection

Seventy-six cooperators returned 165 data sets over the 5 years of data collection. Only 7.8% of the data sets were complete and 86% were missing covey flushes per hour of hunting effort, our only fall density index. However, 68% contained at least one index of fall abundance (68% contained roadside counts, and 51% fall covey-call counts). Thus, we had 84 data sets suitable for analysis.

Data Evaluation

A multiple regression analysis with stepwise inclusion of variables removed all variables except spring

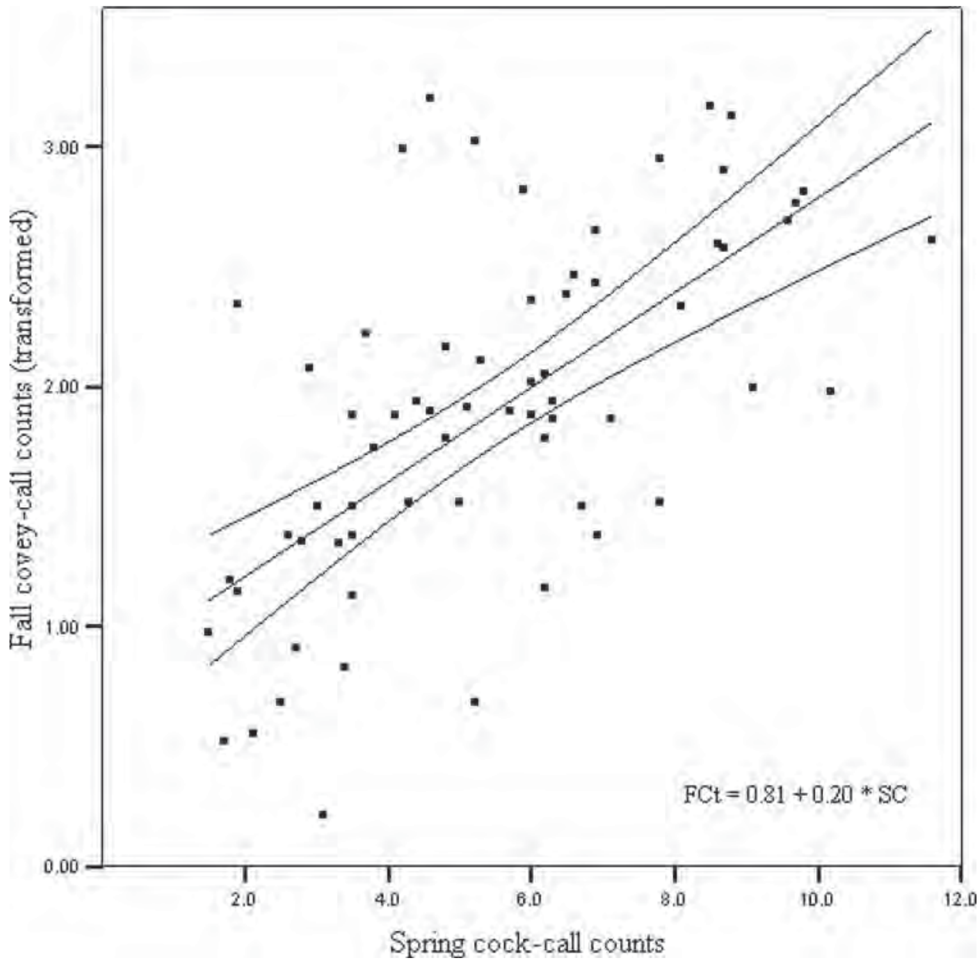

Fig. 2. Fall covey-call counts (transformed; $FC_t = \ln$ [fall covey-call counts + 1]) plotted versus spring cock-call counts for years 1–4 of the Texas Quail Index (2002–2005). Predicted line and 95% confidence intervals around the line are given ($P < 0.01$, $R^2 = 0.41$).

cock-calls from the regression model (Table 1; $P < 0.0001$, $R^2 = 0.440$) indicating spring cock-calls explained 44% of the variation in fall covey-calls for all study sites across all years. An ANCOVA showed variation in predictability among years, ($P = 0.004$, $R^2 = 0.389$), and no correction factor was needed for ecological region ($P = 0.244$). A Fisher's LSD procedure indicated the equation for year 5 was different from all other years ($P = 0.008$) resulting in 2 distinct prediction models. The equation for years 1–4 was $FC_t = 0.81 + 0.20*SC$ ($P < 0.01$, $R^2 = 0.41$; Fig. 2), and the equation for year 5 was $FC_t = -0.04 + 0.51*SC$ ($P < 0.01$, $R^2 = 0.89$; Fig. 3). Individual index results are available in Reyna (2008)

DISCUSSION

We sought to develop a practical and reliable predictor of fall bobwhite abundance that quail managers could use to assess their bobwhite population. The 5-year regression model showed spring cock-calls were significant predictors of FC_t but the R^2 value indicated that only 41% of the variation in FC_t was explained by spring cock-call counts (not a reliable predictor). There was a difference in the relationship between spring cock-call counts and FC_t among years; the equations for years 1–4 did not differ significantly but year 5 yielded an entirely different equation with less variability and more predictability. We were curious if weather variables (e.g., drought conditions) explained any variation in FC_t since other studies have demonstrated correlations between quail abundance and weather (Bridges et al. 2001, Guthery et al. 2001).

We examined the monthly Palmer Drought Severity Index (PDSI) (Palmer 1965) for 2002–2006 and found 2006 (year 5) to be a drought year for the TQI ecological regions and the state of Texas (NOAA 2008). The PDSI is the monthly value (meteorological drought index) generated to indicate the severity of a wet or dry period by measuring the departure from the normal regional moisture supply (Palmer 1965). It is based on the principles of a balance between moisture supply and vegetation demand (Palmer 1965). Bridges et al. (2001) found the PDSI was a better indicator of changes in northern bobwhite abundance than raw precipitation alone, especially in dry ecological regions. Our data support the findings of Bridges et al. (2001) and further show that spring cock-call counts were better indicators of

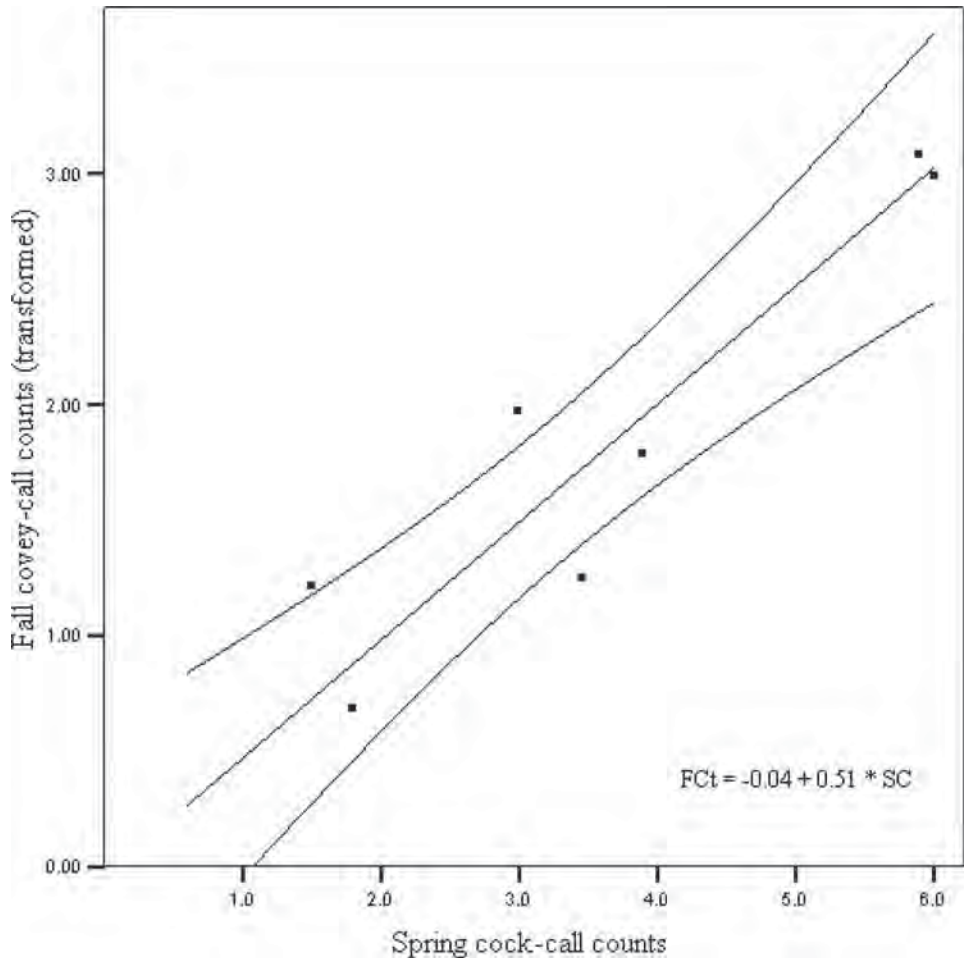

Fig. 3. Fall covey-call counts (transformed; $FC_t = \ln$ [fall covey-call counts + 1]) plotted versus spring cock-call counts for year 5 of the Texas Quail Index (2006). Predicted line and 95% confidence intervals around the line are given ($P < 0.01$, $R^2 = 0.89$).

hunting-season bobwhite abundance during drought years than during non-drought years.

Low breeding success due to heat (Guthery et al. 2001), or drought (Bridges et al. 2001) may be the reason that spring cock-call counts explained 89% of FC_t in the drought year which had a significantly lower percentage of juveniles than in other years (Fig. 4; Reyna 2008). Guthery et al. (2001) recorded temperatures during the nesting season that were sufficient (>39°C) to suppress bobwhite production (by killing bobwhite embryos, chicks, and adults); accelerate the onset of incubation (disrupting synchronous hatching); reduce the length of the laying season (inhibiting renesting and multiple-brooding); and reduce the number of males and females in reproductive condition. These are likely repercussions of the drought year and may explain the variation in breeding success between 'boom' and 'bust' years.

Debate continues regarding the reliability of data collected by citizen scientists (Irwin 1995, Fore et al. 2001, McCaffrey 2005). The large variation in the fall data might be attributed to: (1) inexperience of citizen scientists (Irwin 1995, Fore et al. 2001); (2) inherent variability in discerning unique coveys calling (DeMaso et al. 1992, Irwin 1995); or (3) inconsistent data collection at a site among years, as well as the low rate of return of complete data sets which reduced the sample size and affected the results of the data analysis (Reyna 2008).

Irwin (1995) and Fore et al. (2001) suggested that inexperienced citizen scientists can contribute to inflated variation in data. It can be assumed that as cooperators became more familiar with the protocols, they became better at collecting the data, thus reducing variation in later years. The TQI had additional sources of observer inexperience where untrained family members or friends would collect data when needed, although the occurrence was rare. DeMaso et al. (1992) found variation among observers in the number of coveys identified during morning covey-call surveys, and suggested that identifying unique calls would especially be a concern where fall populations were large (e.g., > 7 coveys/stop; Ellis et al. 1972). This may explain why more variation in the data was observed during non-drought years (when bobwhite population numbers were higher) than in the drought year. The initial cooperator dropped out of the program on 66% of the sites and had to be replaced (Reyna 2008). The new cooperator attended training in each case, but an observer effect may have contributed to errors as a result of different skill levels and hearing abilities of the new cooperator.

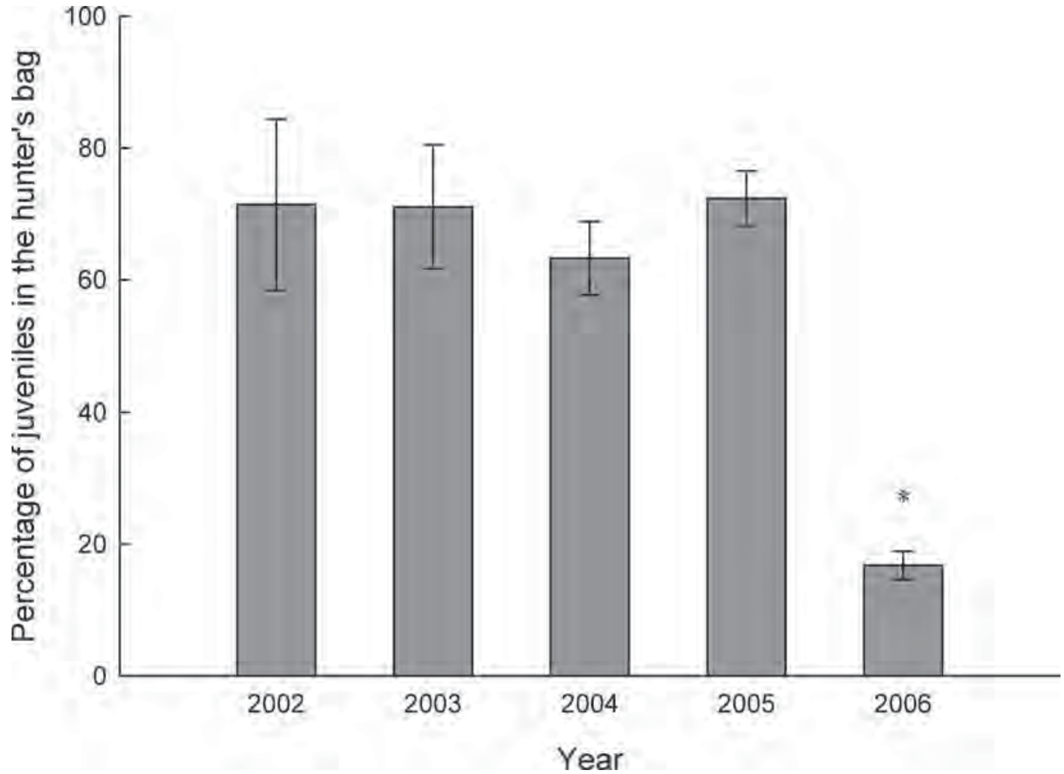

Fig. 4. Mean (± SE) percentage of juveniles in the hunter's bag at 7 Texas Quail Index study sites from 2002 to 2006 (modified from Reyna 2008). Severe drought conditions were experienced across all study sites in 2006, which was significantly* different from all other years ($P = 0.008$).

TQI cooperators were trained and tested on their ability to implement TQI protocols, but were only trained once (at the onset of their participation) and were subsequently responsible for adhering to TQI protocols (Reyna 2008). Some minor protocol violations were made (e.g., inconsistent data collection methods at a site among years) that could have affected our results. Moreover, a few major violations were reported, such as inflating roadside count numbers to attract hunters or missing peak calling times (Reyna 2008). These records were censored before analysis, but the inconsistencies and errors suggest inadequate scientific rigor (Irwin 1995), which should urge caution when evaluating research involving citizen science projects. We believe citizen science is a useful tool to teach citizens about science, conservation, or land stewardship (McCaffrey 2005) and to monitor general trends in bird populations (e.g., Christmas Bird Counts; Lepczyk 2005) but not for scientific data collection in projects that have minimal supervision and do not require annual training.

MANAGEMENT IMPLICATIONS

Spring cock-call counts were better indicators of FC_t in drought years, possibly because of a lower percentage of juveniles in the fall population, or fewer total birds overall. Observer accuracy was more likely to improve with fewer calling birds (Ellis et al. 1972) resulting in less overall variability in the data. A rigorous scientific method was not established but we believe, on a local level, that wildlife managers will find recording spring cock-call counts in conjunction with the Palmer drought indices useful, This should provide a better indication of the trend in their bobwhite abundance as well as an increased ability to predict the declines of their fall bobwhite population abundance in drought years. Seasons with low bobwhite reproduction are the most critical to sustaining a hunting operation because landowners may need to supplement their income with other sources. Our results may be economically and ecologically expedient by providing a 5-month forewarning of a poor upcoming season.

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