Rainfall, El Niño, and Reproduction of Red-cockaded Woodpeckers

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Abstract - This study examines the relationship between Red-cockaded Woodpecker (*Picoides borealis* Vieillot) reproduction and rainfall during May when group members are provisioning nestlings with food. Patterns of variation over a 4-year period of approximately 30 woodpecker groups suggested that the mean number of hatchling deaths was positively related to the amount of rainfall that occurred during May. During the same 4 years, the mean number of young fledged from nests appeared to be inversely related to May rainfall. Observations of nestling provisioning behavior during four breeding seasons indicate that group members slow down or stop feeding nestlings during periods of heavy rainfall. During a 20-year period, total May rainfall was related to the percentage of woodpecker groups producing fledgling-sized young in cavities (r_s = -0.56, P = 0.0097) and the occurrence of El Niño events (r_s = -0.50, P = 0.0347).

Introduction

The Red-cockaded Woodpecker (*Picoides borealis* Vieillot) is a cooperatively breeding species indigenous to the southeastern United States (Conner et al. 2001). Young woodpeckers, typically males from previous nesting efforts, often remain with the breeding pair and assist in subsequent nesting efforts by incubating eggs, feeding and brooding young, excavating cavities, and helping to defend the group's territory (Conner et al. 2001, Lennartz et al. 1987, Ligon 1970, Walters et al. 1988).

Weather can affect behavior and reproduction in birds. Air temperature, solar insolation (Grubb 1975, 1977), and wind force (Hansson 1997) are known to influence avian foraging behavior. Drought is known to depress the reproductive success of Mexican Jays (*Aphelocoma ultramarina* Bonaparte) in the southwestern United States (Li and Brown 1999). Rainfall also may have an influence on avian reproduction. Rainfall significantly reduced nestling provisioning rates in Great Tits (*Parus major* Linnaeus) (Radford et al. 2001) and foraging efficiency of Blue Swallows (*Hirundo atrocaerulea* Sundevall) (Evans and Bouwman 2000), and had a negative effect on Skylark (*Alauda arvensis* Linnaeus) body condition and growth rates (Donald et al. 2001). Precipitation has been linked to Mexican Spotted Owl (*Strix occidentalis lucida* Nelson) reproductive output (Seamans et al. 2002), and rainfall and temperature has been linked to Northern Spotted Owl

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(*Strix occidentalis caurina* Merriam) survival, reproductive output, and recruitment (Franklin et al. 2000). Pasinelli (2001) observed that rainfall during the nestling phase was negatively associated with breeding performance in Middle Spotted Woodpeckers (*Dendrocopos medius* Linnaeus) and suggested that this resulted from a decrease in nestling provisioning rates. Observations of adult Red-cockaded Woodpeckers feeding young in nest cavities (Conner et al. 1999, Schaefer 1996) suggested that rainfall might reduce or curtail provisioning activities.

El Niño Southern Oscillation, which involves sea surface temperature changes in the equatorial Pacific Ocean, has a global influence on precipitation and temperature patterns (Barsugli et al. 1999, Kiladis and Diaz 1989, McCabe and Denttinger 1999). Because El Niño events are associated with increased rainfall in the southeastern United States (Beckage et al. 2003, Hansen et al. 1998, Peters et al. 2003), it is possible that El Niño Southern Oscillation could affect variation in Red-cockaded Woodpecker reproductive success there.

We studied annual variation in Red-cockaded Woodpecker nest productivity in eastern Texas and posed the following questions. Is there a relationship between May rainfall and annual variation in Red-cockaded Woodpecker nest productivity? Does heavy rainfall affect provisioning rates of nestlings? Is May rainfall in eastern Texas associated with El Niño Southern Oscillation?

Study Areas and Methods

Study areas

We studied Red-cockaded Woodpecker nesting biology in longleaf (*Pinus palustris* Miller) and loblolly (*P. taeda* Linnaeus)–shortleaf (*P. echinata* Miller) pine habitats in the Angelina (31°N15'N, 94°N15'W) and Davy Crockett national forests (31°N21'N, 95°N07'W) in eastern Texas during 1990, 1991, 1999, and 2000. The edges of these two national forests are separated by less than 20 km. Observations of Red-cockaded Woodpecker nesting biology were also made in longleaf pine habitat in the Vernon Ranger District of the Kisatchie National Forest (31°01'N, 93°02'W) in west-central Louisiana during 1992 and 1993.

Nestling provisioning rates and heavy rainfall events

We observed Red-cockaded Woodpecker nestling provisioning rates (n = 62 nests) in longleaf pine habitat in the Vernon Ranger District of the Kisatchie National Forest in west-central Louisiana during the 1992 and 1993 breeding seasons (Conner et al. 1999) and in Texas in the Angelina and Davy Crockett national forests during 1990 and 1991 (Schaefer 1996). We determined nestling provisioning rates at 12 to 19 nests each year (three 3-h visits per nest) during the first 3 hours after the breeding male left his nest cavity when nestlings were 8-, 20-, and 23-days-old (9 hours of observation for each nest). We noted days when heavy rain events occurred during the 3-hour periods of provisioning observation. The analysis on nestling provisioning rates was limited to days of heavy rain and days of no rain. Light rain showers were not included in the analysis because they did not stop Red-

cockaded Woodpecker provisioning of nestlings. We eliminated observations for the analysis on days when rain events could not be classified as heavy, and when lightning events prevented completion of the 3-h observation period. Only completed 3-h observation periods were used in the analysis (n = 170 at 62 nests). We used a Mann-Whitney U test (Siegel 1956) to examine our prediction that rainfall was associated with decreased rates of provisioning food to nestlings. We adjusted the number of provisioning trips for the number of nestlings in the cavity.

Reproductive success, May rainfall, and El Niño Southern Oscillation

For 20 years (1983–2002) in the Angelina National Forest, we visited all active Red-cockaded Woodpecker cavity trees, located nest trees, and determined the number of woodpecker groups that produced nestlings that were at least 14 days old and groups that produced no fledglings. Unfortunately, we did not collect woodpecker group size or breeder age and experience data for all groups during most of the 20 years. Using the assumption in this instance that 14-day-old nestlings indicated a successful nest, we used a Spearman correlation analysis to examine relationships between Red-cockaded Woodpecker nest success, rainfall during May, and El Niño events (El Niño year versus not an El Niño year) as determined by the National Oceanic and Atmospheric Administration (NOAA 2002). El Niño events were considered to be ordinal data (presence versus absence) when Pacific equatorial water temperatures exceeded a threshold temperature (0.5 °C above normal; Siegel 1956:25).

May rainfall and nest productivity

We studied Red-cockaded Woodpecker nest productivity at 99 nests in longleaf and loblolly-shortleaf pine habitats on the Angelina and Davy Crockett national forests during the 1990, 1991, 1999, and 2000 breeding seasons (McCormick et al. 2004, Schaefer 1996). Clusters were checked at least every 5 days for nesting activity. If no birds were observed flying from the cavity entrance, we gently scraped and tapped at resin wells on the cavity trees that had the greatest amount of activity in an attempt to flush incubating or brooding woodpeckers from the cavities. If an adult bird was observed flying from the cavity or was seen in the area, we inspected the cavity by climbing the tree and using a flashlight and mechanic's mirror (1990–1991), or used a Tree-Top II™ Peeper Video system from the ground (1999–2000) (Richardson et al. 1999). If no nest was found, all trees were examined again for possible nesting at the next inspection. If eggs were found in the cavity, another visit was scheduled for 3 days later to see if the clutch was complete. Woodpecker group size was determined for each group during April and May of each year by counting group members as they assembled in the morning to commence foraging or as they returned to cavity-tree cluster sites in the evening prior to roosting.

Confirmed Red-cockaded Woodpecker nest cavities were monitored to determine clutch size, initial number of hatchlings, and number of nestlings surviving beyond day 22 as a measure of fledging success. Nestling age was

determined using criteria developed by Ligon (1971). To prevent premature fledging that might result from nest disturbance, we ceased internal nest inspections at day 22 as required by the US Fish and Wildlife Service. Post-fledging observations of young woodpeckers being fed by adults were used to verify measures of fledging success. Eighty-three of the 99 nests studied (83.8%) produced fledglings and were used to examine relationships between the mean number of Red-cockaded Woodpecker fledglings per nest, mean number of hatchling deaths per nest, and total rainfall during May (Fig. 1) and the mean number of eggs per nest and total rainfall during April (Fig. 2). Sixteen nests were not included in the graph because nest failure was known to be caused by factors (e.g., predation) other than weather and nestling provisioning rate. Our sample size (n = 4) was too low to calculate any statistical analyses, and the graph was plotted solely to examine patterns that might be present (Figs. 1 and 2). May was selected as the month to examine relationships between reproductive success and rainfall because it is the month of the breeding season when most nestling provisioning by adults takes place. Most woodpecker groups begin laying eggs from mid- to late April, and most young have fledged by early June (Conner et al. 2001). April rainfall was compared with the mean number of eggs laid because of the possibility that rainfall might affect the ability of females to lay eggs (Fig. 2). Past and recent measurements of total rainfall in April and May were obtained from the Arthur Temple College of Forestry, Stephen F. Austin State University in

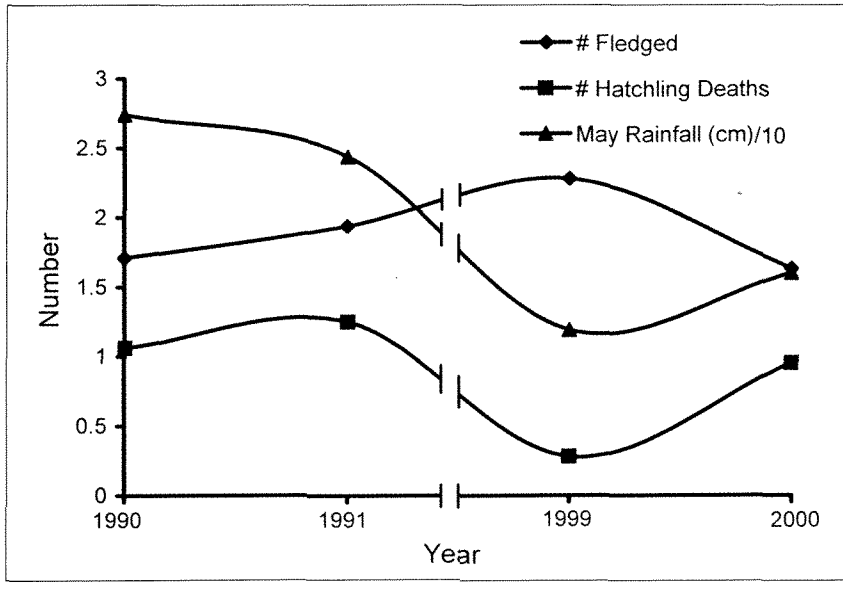

Figure 1. Red-cockaded Woodpecker nest productivity as measured by mean number of fledglings per nest, mean number of hatchling deaths per nest, and total rainfall (cm)/10 during May in eastern Texas (n = 83). Lines connecting means are presented solely to facilitate visualization of patterns; they do not reflect mean values between 1991 and 1999.

Nacogdoches, TX, at a weather station that is approximately equidistant from the Angelina and Davy Crockett national forests (Chang et al. 1996).

Results

The rate at which adult Red-cockaded Woodpecker group members provisioned nestlings in Texas (1990 and 1991) and Louisiana (1992 and 1993) was associated with rainfall events during the 3-hour period after the breeding male left the nest cavity. Red-cockaded Woodpeckers made 14.33 ± 3.1 SE provisioning visits to nests (trips/nestling) when rain was falling (n = 8) versus 22.85 ± 0.7 when it was not raining (n = 162) (Mann-Whitney U test, U = 326.0, Z = -2.62, P = 0.0043).

Over the 20 years from 1983 through 2002, the percentage of Red-cockaded Woodpecker groups on the Angelina National Forest that produced 14-day-or-older nestlings was negatively related to the total rainfall during May (r_s = -0.56, P = 0.0097). El Niño occurrence was related to total rainfall during May (r_s = -0.50, P = 0.0347), but was not significantly related to the percentage of woodpecker groups that produced 14-day-or-older nestlings (r_s = -0.28, P = 0.2530). A plot of the data from the 83 Red-cockaded Woodpecker groups we studied during 1990, 1991, 2000, and 2001 in eastern Texas suggests the possibility that Red-cockaded Woodpecker nesting activity and nest success was associated with total rainfall during May (Fig. 1). Mean number of young fledged from nests appears to

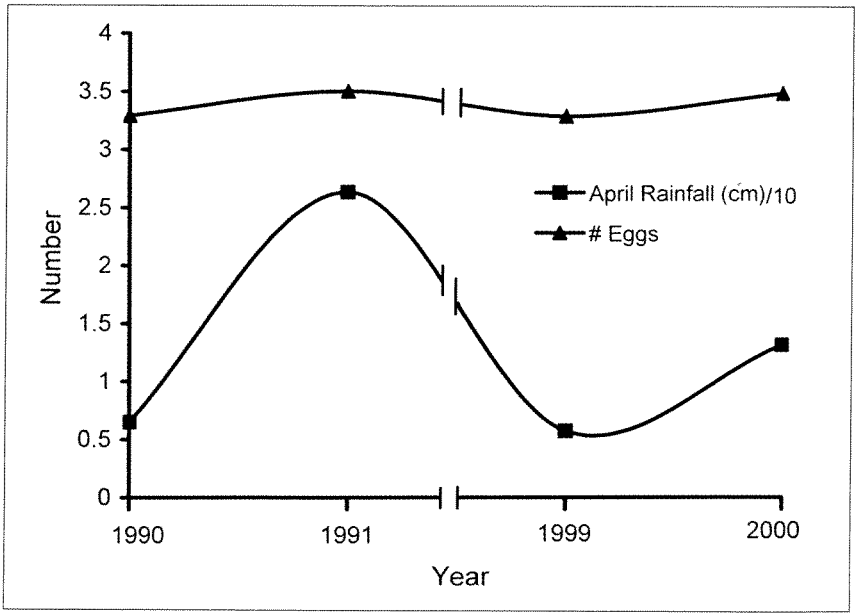

Figure 2. Red-cockaded Woodpecker nest productivity as measured by mean number of eggs per nest (clutch size) and total rainfall (cm)/10 during April in eastern Texas (n = 83). Lines connecting means are presented solely to facilitate visualization of patterns; they do not reflect mean values between 1991 and 1999.

be inversely related to total rainfall during May, whereas mean number of hatchling deaths appears to have decreased as rainfall during May decreased.

A plot of total rainfall in April and mean number of eggs laid per nest suggests that rainfall in April did not decrease the ability of females to lay eggs (Fig. 2). In fact, mean clutch size appears to have increased as total rainfall in April increased.

Discussion

Rainfall appears to influence the breeding performance of Red-cockaded Woodpeckers. The productivity of Red-cockaded Woodpecker nests appears to be related to the total rainfall that occurs during the month of May, a period when the woodpeckers provision growing nestlings with food. April rainfall did not appear to have a negative affect on mean clutch size. Our results were similar to the observations of Pasinelli (2001) on Middle Spotted Woodpeckers. Heavy rainfall reduced the number of provisioning trips adults made to nestlings. When heavy rainfall commenced, woodpeckers would perch on the boles of pines with their bodies pressed relatively close to the bole. If the cloud cover got very thick and rainfall was heavy, the woodpeckers would often return to their roost cavities and enter, or shelter under horizontal limbs, staying there until the rain ceased. In the evening, Red-cockaded Woodpeckers will go to roost early on overcast days or if it is raining (Conner et al. 2001). Because adults made fewer trips to provision nestlings when rainfall occurred, rain may affect the nutritional condition and health of nestlings and ultimately their survival. Rain during daylight hours, but particularly during early morning when young are being fed following their nocturnal fast, may be related to hatchling death and the number of young eventually fledged from nest cavities. Neal et al. (1993) reported increased Red-cockaded Woodpecker nestling deaths in association with increased rainfall and abnormally low temperatures in Arkansas.

Variations in weather patterns associated with global climate change that affect seasonality and amount of rainfall in the southeastern United States may have a long term influence on avian reproduction. Brown et al. (1999) suggest that global warming may cause Mexican Jays to breed earlier in the southwestern United States. Climate change has affected phenology of egg laying and reproductive success in Red-cockaded Woodpeckers (Schiegg et al. 2002). Over the past two decades female Red-cockaded Woodpeckers have laid eggs increasingly earlier. Females that have changed mates and inbred birds apparently have not adjusted to lay eggs earlier and have suffered a reproductive penalty (Schiegg et al. 2002).

El Niño events are influenced by climate change and are associated with increased rainfall in the southeastern United States over an area that covers nearly the entire range of extant Red-cockaded Woodpecker populations (Beckage et al. 2003, Hansen et al. 1998). If weather patterns change so that more rainfall occurs during May in the South, efforts to recover this endangered woodpecker could be hampered by reduced nest productivity, particularly in the non-coastal regions of the southeast. Coastal regions may

accrue a net benefit because the potential negative impact of El Niño events on reproduction might be offset by a reduction of hurricane frequency and severity (Elsner and Jagger 2004), which are known to devastate Red-cockaded Woodpecker populations (Hooper and McAdie 1995).

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