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DIET OF NESTLING RED-COCKADED WOODPECKERS AT THREE LOCATIONS

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Abstract.—We conducted a 2-yr study of the nestling diet of Red-cockaded Woodpeckers (*Picoides borealis*) at three locations to determine how it varied among sites. We photographed 5939 nest visits by adult woodpeckers delivering food items for nestlings. In 1994, we located cameras near three nest cavities on the Lower Coastal Plain of South Carolina and near two cavities at the Savannah River Site, which is on the Upper Coastal Plain. In 1995, cameras were installed on the Savannah River Site and in the Piedmont National Wildlife Refuge, Georgia. The cameras recorded adults bringing 33 different types of food to nestlings. Wood roaches (Blattoidea: Blattellidae, *Parcoblatta* spp.) were the most common food composing 50% of the diet overall. They were also the most common prey at each location and for all but one of the woodpecker groups studied. Wood roaches were recorded in 26% of the visits photographed on the Lower Coastal Plain and 62% of the nest visits on the Upper Coastal Plain in 1994. In 1995, wood roaches were recorded in 57% and 50% of the visits on the Upper Coastal Plain and Piedmont, respectively. Woodpeckers on the Lower Coastal Plain used blueberries (*Vaccinum* sp.) and sawfly larvae (Hymenoptera: Diprionidae, *Neodiprion* sp.), two dietary items not commonly used at the other locations. Adults at two locations providing snail shells to nestlings possibly as an additional source of calcium. Morista's index of diet overlap (*C*) ranged from 0.94 to 0.99 for breeding males and females in the same group, from 0.63 to 0.99 among groups at the same location, and from 0.68 to 0.96 among locations. Because diet overlap of Red-cockaded Woodpecker nestlings at different geographical locations was within the range that occurred among groups at the same location, we conclude that nestling diets are similar across the geographical area studied, and that it varies little from year to year.

LA DIETA DE CRÍAS DE *PICOIDES BOREALIS* EN TRES LOCALIDADES

Sinopsis.—Condujimos un estudio de la dieta de las crías de *Picoides borealis* en tres áreas para deterninar como varía entre estas. Fotografiamos 5939 visitas de los adultas llevando alimento a sus crías. En el 1994 colocamos cámaras cerca de tres cavidades en la planicie costera baja de Carolina del Sur y cerca de dos cavidades en el área del Río Savannah, que se halla en la planicie costera superior. En el 1995 se instalaron cámaras en el área del Río Savannah y en el Refugio Nacional de Vida Silvestre de Piedmont. Las cámaras documentaron adultos trayendo 33 diferentes tipos de alimentos a las crías. Individuos de *Parcoblatta* spp. (Blattoidea: Blattellidae) fueron los más comúnes, sumando 50% de la dieta total. También fueron el alimento más común en cada lugar y en todos menos uno de los grupos estudiados. Se registraron estas en el 26% de las visitas fotografiadas en la planicie costera del sur y en el 62% de las visitas a nidos en la planicie costera superior en 1994. En el 1995,

esta presa se registró en 57% y 50% de las visitas a la planicie costera superior y en el Piedmont respectivamente. Las aves de la planicie costera del sur alimentaron frutos de *Vaccinum* sp. y larvas de *Neodiprion* sp. (Hymenoptera: Diprionidae), dos recursos dietéticos poco usados en las otras lugares. Los adultos de dos localidades proveyeron conchas de caracoles, posiblemente como fuente adicional de calcio. El índice de Morista de sobrelapamiento en dieta (*C*) varió del 0.94 al 0.99 para machos y hembras reproductivos en el mismo grupo, de 0.63 a 0.99 entre grupos en el mismo lugar, y entre 0.68 y 0.96 entre lugares. Concluímos que las dietas de las crías son similares a travéz de las áreas geográficas estudiadas, y que varían poco entre año y año debido al sobrelapamiento de crías de *Picoides borealis* en diferentes lugares geográficos se halló del mismo grado que lo ocurrido entre los grupos en la misma localidad.

The Red-cockaded Woodpecker, (*Picoides borealis*), is a federally listed endangered species that inhabits pine forests throughout the southern United States from Virginia to Texas. The larger, more stable populations are primarily in the Coastal Plain; the more vulnerable populations are in the Piedmont (James 1995). Unlike other woodpecker species, Red-cockaded Woodpeckers construct roosting and nesting cavities in live pine trees (Steirly 1957), which they use for a number of years. Over 95% of their foraging time is spent on the surfaces of live trees in the forested areas surrounding those cavities (Hooper and Lennartz 1981, Porter and Labisky 1986).

A variety of techniques have been used to investigate the diet of Red-cockaded Woodpeckers, including analysis of gut content (Beal 1911, Hess 1997), direct observation (Harlow and Lennartz 1977) and photography (Hanula and Franzreb 1995). Studies have revealed that Red-cockaded Woodpeckers eat common arthropods, such as wood roaches (Blattoidea: Blatellidae, *Parcoblatta* spp.), ants (Hymenoptera: Formicidae, *Crematogaster* sp. and *Camponotus* spp.), centipedes (Scolopendromorpa), spiders (Araneae), and a variety of insect larvae. Although these studies have identified common dietary items, they do not agree on which items constitute the bulk of the bird's diet. For example, ants were the most common prey reported from adults in a rangewide study (Beal 1911) and in a Florida population (Hess and James 1998). However, insect larvae and wood roaches were the most common prey fed to nestlings on the Lower (Harlow and Lennartz 1977) and Upper (Hanula and Franzreb 1995) Coastal Plain of South Carolina, respectively. Stomach flushes from nestlings in a Florida population contained approximately equal proportions of ants, beetles (larvae and adults), spiders, and centipedes as the main food items on a volume basis (Hess and James 1998). Hanula and Franzreb (1995) suggested several reasons for the variation including natural fluctuations in prey populations over time, differences in methodology, or variations in prey abundance at different locations. A better understanding of the temporal and geographical differences or similarities in the Red-cockaded Woodpecker diet will help us determine which prey are consistently important and facilitate development of better forest management guidelines for foraging areas. We report the results of a study investigating the diet of nestlings over a 2-yr period in three phys-

iographic provinces. In addition, we compare this information with data collected in 1993 (Hanula and Franzreb 1995) to determine how the bird's diet has varied over a 3-yr period at one location.

METHODS

We photographed (Hanula and Franzreb 1995) adult Red-cockaded Woodpeckers returning to nest cavities to feed their young. Using 35-mm cameras with long focal length lenses (500 mm), flashes, special camera backs that held 250 exposures, and infra-red tripping devices. We put the cameras in water-tight boxes mounted on 4-m-tall tripods and positioned them as close to the nest cavities as possible, although no closer than 4 m from the cavity tree. We changed the flash batteries daily (Monday–Friday), and the Ektachrome 200 slide film was replaced every other day (Monday, Wednesday, and Friday). We chose to record for long periods of time at each nest rather than moving the cameras frequently from nest to nest to minimize disturbance of the woodpeckers in a given area.

We used two cameras during the nesting season (May and June) in 1994 and 1995 at the Savannah River Site, which is located on the Upper Coastal Plain of South Carolina (33.2°N, 81.4°W). Most stands harboring Red-cockaded Woodpeckers on the site are composed of longleaf pine (*Pinus palustris*) growing in deep sandy soils but foraging areas also contain some loblolly (*P. taeda*) and slash pines (*P. elliotti*).

Because most of the Red-cockaded Woodpeckers on the Savannah River Site nested at nearly the same time in 1994, we were only able to record feeding activity by two groups. During the more prolonged nesting season of 1995, we were able to record feeding visits at five nest cavities. The photographic slides taken at each nest cavity were examined with a stereoscope at 12–20× magnification. We recorded the date and time of the nest visit and the type of prey on each slide. Prey were recognizable in 50–60% of the pictures. Some reasons for not being able to recognize prey included; the cameras were out of focus, the flash batteries were discharged resulting in dark pictures, or rain or dew on the camera housing reduced picture quality.

We used two cameras in 1994 on Baruch Forest Science Institute property, which is on the Lower Coastal Plain in Georgetown County, South Carolina (33°N, 79.5°W). We selected this site because it is close to the Francis Marion National Forest and had similar habitat. Before Hurricane Hugo, a category-4 hurricane that came ashore south of Georgetown in 1989, the Francis Marion had the only known naturally increasing population of Red-cockaded Woodpeckers (Hooper et al. 1991). The area is characterized by longleaf pine on the beach ridges grading into loblolly pine on the lower, moist sites.

In 1995, we used two cameras in the Piedmont on the Piedmont National Wildlife Refuge (NWR) near Round Oak, Georgia (33.1°N, 83.7°W). The Piedmont NWR has a more hilly topography than the Savannah River Site and contains stands of loblolly and some shortleaf pine, (*P. echinata*), with a denser understory of predominantly sweetgum, (*Liq-*

uidambar styraciflua), and water oak, (*Quercus nigra*), growing on heavily eroded clay soils. We monitored feeding activity at nest cavities of three groups.

We used Morista's index of diet overlap (Litvaitus et al. 1996), which is considered the least biased of the diet overlap estimators (Smith and Zaret 1982), to quantify the similarity of Red-cockaded Woodpecker prey within and between locations. The formula for Morista's index is

$$C = 2 \sum P_{ij}P_{ik} \Big/ \left\{ \sum^{n} P_{ij}[(n_{ij}-1)/(N_j-1)] + \sum^{n} P_{ik}[(n_{ik}-1)/(N_k-1)] \right\}$$

where: P_{ij} = proportion item i is of total food used at j location or nest cavity; P_{ik} = proportion item i is of total food used at k location or nest cavity; n = total number of food items; n_{ij} = number of individuals of item i in samples from location or nest cavity j; n_{ik} = number of individuals of item i in samples from location or nest cavity k; N_j = total number of individuals of each food item in samples of species j; N_k = total number of individuals of each food item in samples of species k. We also used Morista's index to compared prey overlap among years using data we had gathered from 1993 through 1995 at the Savannah River Site. In addition, we compared the overlap in prey selected for nestlings by breeding males to females within three groups studied in 1993, because males and females forage at different positions on the trees (Ligon 1968, Skorupa 1979, Ramey 1980, Hooper and Lennartz 1981) and may select different prey.

RESULTS

We recorded 5939 nest visits at the Savannah River Site, Baruch Forest Science Institute, and the Piedmont NWR in which prey presented to nestlings were identifiable (Table 1). Wood roaches were the most common prey, comprising 50 percent of the nestling diet overall. Other common dietary items included caterpillars (Lepidoptera larvae), spiders, wood borer larvae (Coleoptera: Cerambycidae or Buprestidae), adult beetles, ants, and centipedes. The diet also included uncommon food items like blueberries (*Vaccinum* sp.), snail shells (Pulmonata), a preying mantid (Mantodea; Mantidae), a hawk moth (Lepidoptera: Sphingidae), and a lacewing (Neuroptera: Chrysopidae).

Wood roaches were the most common arthropod taken in 1994 and 1995 at all three locations (Table 2). Only the diets of birds on the Lower Coastal Plain consisted of less than 50% wood roaches. However, they were still the most common prey, comprising 26% of the diet at that location. Red-cockaded Woodpeckers on the Lower Coastal Plain were the only ones that used blueberries (15.9% of the visits) and they also used sawfly larvae (Hymenoptera: Diprionidae, *Neodiprion* sp.). Otherwise, woodpeckers on the Upper and Lower Coastal Plain sites selected similar prey. The estimate of dietary overlap (C) between the two sites was 0.68.

TABLE 1. Total number and percent of nest visits made by Red-cockaded Woodpecker adults with each food type. Data represent all visits to nest cavities on the Lower and Upper Coastal Plain of South Carolina and the Piedmont of Georgia recorded over a 2-year period.

Food item[a]	Number of visits	% of visits
Wood roach (Blattoidea: Blatellidae)	3005	50.6
Caterpillar (Lepidoptera)	461	7.7
Spider (Araneae)	412	6.9
Wood borer larva (Coleoptera: Cerambycidae or Buprestidae)	250	4.2
Beetle adult (Coleoptera)	238	4.0
Ant larvae and/or adults (Hymenoptera: Formicidae)	227	3.8
Blueberry (*Vaccinum* sp.)	226	3.8
Centipede (Scolopendromorpha)	221	3.7
Insect larvae	174	2.9
Insect	165	2.8
Insect larva	146	2.4
Hymenoptera larva	95	1.6
Insect adult	66	1.1
Lepidoptera pupa	58	1.0
Sawfly larvae (Hymenoptera: Diprionidae, *Neodiprion* sp.)	52	0.9
Beetle larva (Coleoptera)	47	0.8
Ground beetle adult (Coleoptera: Carabidae)	14	0.2
Hymenoptera adult	11	0.2
Cicada (Homoptera: Cicadidae)	10	0.2
Beetle larvae (Coleoptera)	8	0.1
Cricket (Orthoptera: Gryllidae)	8	0.1
Beetle pupa (Coleoptera)	8	0.1
Hemiptera adult	6	0.1
Fly adult (Diptera)	5	0.1
Snail shell (Pulmonata)	5	0.1
Long-horned grasshopper (Orthoptera: Tettigoniidae)	5	0.1
Grasshopper nymph (Orthoptera: Acrididae)	4	0.1
Silverfish (Thysanura: Lepismatidae)	4	0.1
Harvestman (Phalangidae)	3	>0.1
Shield-back bug (Hemiptera: Scutelleridae)	2	>0.1
Hawk moth (Lepidoptera: Sphingidae)	1	>0.1
Lacewing (Neuroptera: Chrysopidae)	1	>0.1
Preying mantid (Mantodea: Mantidae)	1	>0.1

[a] Prey designated as plural mean that more than one individual was brought to the cavity in each trip.

The diet of nestlings in Georgia's Piedmont was similar to the Upper Coastal Plain site, as evidenced by the Morista index of 0.96 for diet overlap between the two sites. Birds at both locations presented high proportions of wood roaches (Table 2). They also used relatively high numbers of caterpillars, which were primarily coneworms (Lepidoptera: Pyralidae, *Dioryctria* spp.) that bore into and feed on pine cones. The two sites differed in the number of wood borer larvae fed to nestlings and the proportion of prey categorized as insects. Most of the prey listed as insects were probably roaches or beetles.

TABLE 2. Comparison of the percentage of Red-cockaded Woodpecker nest visits with the most common food items during 1994 on the Upper and Lower Coastal Plain (CP) and 1995 on the Upper CP and Piedmont.

	Percent nest visits			
	1994[b]		1995[c]	
Food item[a]	Upper CP	Lower CP	Upper CP	Piedmont
Wood roach	62.4	26.0	56.6	49.9
Caterpillar	4.6	9.1	8.3	9.3
Spider	6.5	7.2	7.3	5.2
Wood borer larva	6.8	1.2	5.5	0.5
Beetle adult	1.4	6.0	3.8	5.7
Ant larvae and/or adults	4.7	7.2	2.2	0
Blueberry	0	15.9	0	0
Centipede	0	4.9	4.6	3.2
Insect larvae	0.5	6.0	3.2	1.0
Insect	0.5	2.2	1.8	10.8
Insect larva	1.8	1.3	2.9	4.1
Hymenoptera larva	3.3	2.1	0.3	0.9
Lepidoptera pupa	2.2	0.1	0.1	2.4
Sawfly larvae	0.2	3.6	0.0	0.0
Beetle larva	1.2	1.7	0.3	0.3

[a] Prey designated as plural mean that more than one individual was brought to the cavity in each trip.

[b] Total number of visits with all food items in 1994 was 1526 and 1425 for the Upper and Lower CP, respectively.

[c] Total number of visits with all food items was 2259 and 716 in 1995 for the upper CP and Piedmont, respectively.

Intra-site variation in the number of trees available for foraging was greatest among the three groups on the Lower Coastal Plain. In particular, group 22 had fewer mature pine stems available relative to the other two groups at that location due to Hurricane Hugo; so we compared the nestling diet among those groups to see if lower forage substrate affected prey used. Wood roaches were consistently taken in about the same proportions by all three groups (23.3–27.3%). Comparison of the three groups showed that the two upland groups, 2 and 7, had the least similar diet ($C = 0.63$) while groups 22 and 2 had the most similar ($C = 0.94$).

By including data from 1993, we had 5451 observations of Red-cockaded Woodpecker nest visits with identifiable prey taken over a 3-yr period on the Savannah River Site. Comparison of nestling diet overlap among years at that location showed a high degree of similarity ($C = 0.96$ to 0.98). Comparison of breeding males to females in the same groups showed that they also have a high degree of similarity in prey selection of items fed to nestlings.

DISCUSSION

Diets of nestling Red-cockaded Woodpeckers were similar regardless of the type of foraging substrate (longleaf versus loblolly pine), the amount

of substrate available, the year of observation, or the geographic location in Georgia or South Carolina. These data, as well as data from earlier studies (Harlow and Lennartz 1977, Hanula and Franzreb 1995), demonstrate that wood roaches are an important part of a nestling's diet in the area studied. Only on the Lower Coastal Plain did the proportion of visits where roaches were fed to nestlings fall below 50%. We are uncertain whether fewer roaches were available, or other prey were more abundant. However, we suspect the latter since recent studies suggest that adults present prey to nestlings in proportion to their availability on the bark (J. Hanula, unpubl. data).

Blueberries were a large portion of the diet of two Red-cockaded Woodpecker groups on the lower Coastal Plain. The site had an abundance of "high bush" blueberries that were not found on the Savannah River Site or the Piedmont NWR (J. Hanula, pers. obs.). In addition, the berries ripened early in 1994 (D. Lipscomb, pers. obs.), making them a readily available food source during the breeding season. Ligon (1971) reported the use of blueberries in the nestling diet of a group in Florida, and Hooper and Lennartz (1981) reported adults foraging on blueberries in the vicinity of Charleston, South Carolina. Red-cockaded Woodpeckers also use the fruits of other plants such as wild cherry, (*Prunus serotina*), wax myrtle (*Myrica cerifera*), sweet bay (*Magnolia virginiana*), and poison ivy, (*Rhus radicans*) (Baker 1971, Hooper and Lennartz 1981, Hess and James 1998).

Red-cockaded Woodpeckers on the Lower Coastal Plain also presented sawfly larvae to nestlings. Sawflies were primarily used by Red-cockaded Woodpeckers in group 22, where Hurricane Hugo had damaged foraging territories. This area was composed of very sparse stands of mature loblolly pine with an understory of 1–2 m loblolly pine saplings. The sawfly larvae, *Neodiprion* sp., feed gregariously on pine foliage near the ends of branches (Anderson 1960). In almost every case, four to five sawflies were brought back to the nest cavity in each visit. The use of sawflies is further evidence that Red-cockaded Woodpeckers readily adapt to available food sources as suggested by Hanula and Franzreb (1995). Caterpillars, primarily coneworms, constituted 8.6 and 13.1% of the nestling diet in groups 2 and 7, but only 0.3% in group 22; possibly because the latter had only about one-third the number of mature, cone producing trees.

During 1994 and 1995, we recorded five visits in which adults carried snail shells to the nestlings. Following prescribed burns, snail shells are often visible on the ground where they are easily collected. These are the first records of Red-cockaded Woodpeckers supplementing the diet of nestlings with a possible calcium source. Four of the photographs were taken at the Upper Coastal Plain location in 1994 and 1995, and one was taken at the Lower Coastal Plain site in 1994. Of the five visits, one was made by a helper male (a non-breeding member of the group), two by a breeding male, and one by a breeding female. Birds were not banded at the Lower Coastal Plain site so the sex and breeding status were unknown. Birds were also photographed carrying white objects with sharp corners

and straight edges. Although they could not be clearly identified, we suspect the objects were shell or bone fragments. Repasky et al. (1991) observed adult females collecting bone fragments from raptor pellets during egg laying, either eating them immediately or caching them in the bark. However, they were unable to observe them collecting these potential sources of calcium during the time they were feeding nestlings. It is unclear if calcium from snail shells is important to Red-cockaded Woodpecker nestlings.

This study and others (Beal 1911, Harlow and Lennartz 1977, Hanula and Franzreb 1995, Hess and James 1998) demonstrate that Red-cockaded Woodpeckers feed nestlings a wide variety of food items, but it appears that relatively few common arthropods constitute the bulk of their diet. Dietary overlap analyses show that breeding males and females selected the same prey for nestlings, and that the nestling's diet at the Savannah River Site varied little from year to year. We used the Savannah River Site as a reference location for comparison of dietary overlap between locations and found that the diet of Red-cockaded Woodpeckers on the Lower Coastal Plain site differed more from the Upper Coastal Plain than from the Piedmont. However, the diet overlap of the Upper and Lower Coastal Plain was 0.68, which is within the range of variation that we observed among individual bird groups at a single location. For example, diet overlap among groups ranged from 0.63 to 0.95 on the Lower Coastal Plain, from 0.63 to 0.93 on the Piedmont, and from 0.74 to 0.99 on the Upper Coastal Plain. Thus, the variation in nestling diets in the relatively homogenous habitat at each geographic location was comparable to the variation in diets across locations. These data suggest that the prey used to feed nestlings does not vary greatly across the geographical area we studied. Thus, it appears that forest management guidelines or strategies for foraging territories of this endangered species can be applied across large areas, and that they do not need to be site specific.

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