Wilson Bull., 107(3), 1995, pp. 485–495

ARTHROPOD PREY OF NESTLING RED-COCKADED WOODPECKERS IN THE UPPER COASTAL PLAIN OF SOUTH CAROLINA

JAMES L. HANULA[1] AND KATHLEEN E. FRANZREB[2]

ABSTRACT.—Four nest cavities of the Red-cockaded Woodpecker (*Picoides borealis*) were monitored with automatic cameras to determine the prey selected to feed nestlings. Twelve adults were photographed making nearly 3000 nest visits. Prey in 28 arthropod taxa were recognizable in 65% of the photographic slides. Wood roaches in the genus (*Parcoblatta*) made up 69.4% of the prey fed to nestlings. Other common prey items were wood borer larvae (Cerambycidae or Buprestidae, 5.4%), Lepidoptera larvae (4.5%), spiders (Araneae, 3.6%), and ants (Formicidae, 3.1%). Wood roaches were the only prey items consistently taken by all four groups of birds; they made up 63.3 to 81.6% of the prey observed. Other common prey generally were taken in large numbers only by a single group of woodpeckers. During the breeding season these woodpeckers utilize relatively few common arthropods to feed nestlings. *Received 10 Nov. 1994, accepted 20 Feb. 1995.*

The endangered Red-cockaded Woodpecker (*Picoides borealis*), found throughout the south from eastern Texas to the Atlantic coast, uses live pine tree boles and branches as primary foraging substrate (Hooper and Lennartz 1981, Porter and Labisky 1986), but little is known about their food habits. Determining Red-cockaded Woodpecker prey is critical to understanding the species' foraging ecology. The purpose of this study was to develop an effective system for long-term monitoring of prey use by the Red-cockaded Woodpecker and to develop quantitative prey use data for this endangered species. We examined the diet of nestling Red-cockaded Woodpeckers as part of a larger study on the biology and ecology of insects associated with the bark of live pine trees.

METHODS

We conducted this study on the Savannah River Site (SRS), an 80,269 ha Dept. of Energy (DOE) nuclear production facility in Aiken County, South Carolina. The SRS is on the upper Atlantic Coastal Plain Physiographic Province. Its northern sector consists of uplands and sandhills where conditions are dry and the most common plant communities are longleaf pine (*Pinus palustris*) plantations and natural stands of longleaf pine and turkey oak (*Quercus laevis*). Loblolly pine (*P. taeda*) and bottomland hardwoods predominate on the more mesic areas and in riparian areas. Longleaf, loblolly, and slash (*P. elliotii*) pine stands occupy approximately 14,924 ha, 25,677 ha, and 12,011 ha, respectively (Knox and Sharitz 1990). Most of the stands are under 50 years of age. Potential Red-cockaded Woodpecker nesting

[1] USDA Forest Service, Southeastern Forest Experiment Station, 320 Green St., Athens, Georgia 30602-2044.
[2] USDA Forest Service, Southeastern Forest Experiment Station, Dept. of Forest Resources, Clemson Univ., Clemson, South Carolina 29634-1003.

FIG. 1. Nikon F4 camera with MF-24 multicontrol back and a Nikon SB-25 flash unit in a watertight housing constructed from an electrical box. The infrared sending unit (a) of a Trailmaster 1500 game monitor is attached to the cavity tree above the nest cavity (b) and the receiving unit (c) is attached at the base of the tree. The game monitor detects the presence of a bird at the cavity and trips the camera.

habitat is sparse on the site because only 1521 ha are in pine stands 60 years old or older. The land surrounding the centrally located nuclear production areas has limited public access and is managed by the USDA Forest Service. It contains several Red-cockaded Woodpecker groups containing breeding pairs and one-to-several associated helpers. At the SRS, every woodpecker is banded with a U.S. Fish and Wildlife Service band and a unique set of plastic colored bands. We selected four of the groups at the SRS that had successfully bred during previous years (Franzreb, unpubl. data), and we placed our cameras near their nest cavity trees.

Each of our camera systems (Fig. 1) consisted of a Nikon F4 autofocus camera with a Sigma 500-mm/f7.2 APO lens and a Nikon MF-24 multicontrol back, which held a film cassette allowing 250 exposures and imprinted the time and date of each exposure on the film. We attached a Nikon SB-25 autofocus flash with an auxiliary battery pack to increase the number of flashes between battery changes. We housed each camera in a watertight 15 × 38 × 43 cm fiberglass electrical box (Fig. 1). We cut a 9.5 × 17.5 cm hole in one side of each box and fitted it with a high quality 4-mm-thick glass pane sealed to the box with silicone caulk and held in place with mirror mounting brackets. A second hole 2.5 cm diameter was drilled in the back of the box directly behind the camera viewfinder and similarly fitted with glass. Styrofoam insulation (1.3 cm thick) was attached to the inside of the lid, back, and two sides of the boxes to provide some protection from heat and to reduce camera noise. The camera and flash were supported on separate metal brackets attached to 1.3 cm thick plywood which was fastened to the back of the boxes.

We mounted each camera unit on a 4 m tall Warren and Sweat Co. tripod style deer stand. A mounting and aiming bracket was constructed from 4 × 4 cm angle iron and 2-cm-thick plywood (Fig. 1). This arrangement allowed us to aim the camera vertically by sliding the bottom camera housing attachment bolt through an arc cut in the plywood backing of the aiming bracket. We assembled four of these camera systems and located them at

Red-cockaded Woodpecker Clusters 2, 3, 18, 19, and 39 (numerical designations used by the USDA, Forest Service, Savannah River Forest Station). Because Group 2 nested early and Group 18 was late, we were able to use the four cameras at five nest cavities.

We attached Trailmaster 1500 game monitors to the boles of the nest trees to trip the cameras (Fig. 1). The infrared sending units of the game monitors were 2–3 m above the nest cavities, and the receiving units were attached to the trees 1.5–2 m above the ground. The cameras were automatically tripped when adult birds returned to the nest cavity and interrupted the infrared beam produced by the game monitors. The Trailmaster units were factory-adjusted to have no limit on the number of photographs they would initiate. We set each unit to operate at its most sensitive level and to have a 30-sec delay after a photo was taken to minimize multiple pictures of the same feeding and to eliminate photos of adults leaving the nest with fecal sacs. The Trailmasters were programmed to operated from 06: 00 to 20:30 h EST.

We used Ektachrome 200 slide film. The shutter speed was 1/250 sec, and the autoexposure was set on shutter priority. The flash unit automatically metered existing light through the camera lens and adjusted itself for proper exposure. The rechargeable nickel cadmium batteries used in the flash units were replaced every day. The film was developed as uncut rolls, which allowed us to examine each frame in sequence. Each frame or slide was examined with a stereoscope at 12× magnification, and arthropods were identified to the lowest taxonomic level possible. Time, date, and bird identification based on leg bands was recorded for each slide. Arthropod sampling in the study area (Hanula and Franzreb, unpubl. data) and the arthropod collection at the Georgia Natural History Museum, Athens, Georgia, facilitated prey identification for this study.

We examined the frequency of visits with different prey items for all groups combined, for each woodpecker group separately, and by the age of the nestlings. In addition, we compared the frequency of visits by breeding males, breeding females, and helper males.

RESULTS

The cameras recorded over 3000 nest visits, of which 2978 were of sufficient quality to be used in the analysis. Of the usable slides, 64.5% contained identifiable prey, and 20.9% contained prey items that were visible but could not be identified conclusively. In another 9%, the prey item was not visible, either because the bird's head was turned away from the camera or because its head was already extended into the nest cavity. In 5.6% of the pictures, no food items were visible.

We identified 28 arthropod taxa as prey from the photos (Table 1). Red-cockaded Woodpeckers feed their young either a large prey item or carry a number of small prey at one time. Only rarely did we see a photo of a bird bringing one small item, such as a single roach egg case or a small spider. We used separate listings to show whether the prey consisted of single or multiple items. For example, in Table 1 "insect larva" means that the birds were carrying a single large larva in each visit, while "insect larvae" means that they were carrying many small larvae. The predominant food items were wood roaches (Blattidae) in the genus *Parcoblatta,* which were present in 69.4% of the visits with recognizable prey. Other common prey items were wood-borer larvae (Cerambycidae or Bupres-

TABLE 1

TOTAL VISITS OF 12 ADULT RED-COCKADED WOODPECKERS WITH ARTHROPOD PREY TO FOUR NEST CAVITIES ON THE SAVANNAH RIVER SITE

Prey item	Number of observations	Percent of visits
Wood roach (*Parcoblatta* sp.)	1310	69.4
Wood borer beetle (larva) (Cerambycidae or Buprestidae)	103	5.4
Moth (larva) (Lepidoptera)	85	4.5
Spider (Araneae)	68	3.6
Ant (larvae and adults) (Formicidae)	58	3.1
Longhorned grasshopper (*Atlanticus* sp.)	55	2.9
Centipede (Scolopendromorpha)	53	2.8
Insect (larva) (Insecta)	49	2.6
Insect (larvae) (Insecta)	38	2.0
Beetle (larva) (Coleoptera)	15	0.8
Moth or butterfly (pupa) (Lepidoptera)	11	0.6
Beetle (pupa) (Coleoptera)	6	0.3
Wasp or bee (larva) (Hymenoptera)	4	0.2
Wood roach (ootheca) (Blattidae)	4	0.1
Wood borer (pupa) (Cerambycidae or Buprestidae)	3	0.1
Insect (pupa) (Insecta)	2	0.1
Wasp (adult) (Hymenoptera)	2	0.1
Weevil (adult) (Curculionidae)	2	0.1
Cicada (adult) (Cicadidae)	2	0.1
Short-horned grasshopper (Acrididae)	1	<0.1
Metallic wood boring beetle (adult) (Buprestidae)	1	<0.1

TABLE 1
CONTINUED

Prey item	Number of observations	Percent of visits
Long-horned beetle (adult) (Cerambycidae)	1	<0.1
Fly (adult) (Diptera)	1	<0.1
Click beetle (adult) (Elateridae)	1	<0.1
Cricket (Gryllidae)	1	<0.1
Stonefly (adult) (Plecoptera)	1	<0.1
Silverfish (Lepismatidae)	1	<0.1
Homoptera (nymphs)	1	<0.1

tidae), moth larvae (Lepidoptera), spiders (Araneae), ants (Formicidae), long-horned grasshoppers (Tettigoniidae) in the genus *Atlanticus*, and centipedes (Chilopoda).

We photographed birds feeding both *Crematogaster* sp. and *Camponotus* sp. ants to nestlings, but the majority of our records were of *Camponotus* sp., possibly because they were larger and easier to recognize. In our study, many bird visits with ants were assigned to the "insect larvae" category unless we could identify a recognizable adult among the larvae. In fact, we suspect that this category is primarily composed of visits with ants. Each visit involving ants always included a number of individuals (primarily larvae). Although we were unable to count the number of ants present during each visit, a conservative estimate would be five per visit which would make ants the second most abundant prey item in our study. It is unclear whether they are as important as the numerical data suggest because of their small size. However, some insight might be gained by comparison of oven-dried mass of ants and roaches (Hanula and Franzreb, unpubl. data). The average (N = 596) dry mass of a *Camponotus* spp. ant adult is 0.00418 g or 0.0209 g for five individuals. The average (N = 660) mass of a wood roach is 0.01376 g. Therefore, the estimated total biomass of roaches observed during our study was 18.03 g and that of ants (assuming 5 ants/visit) was 2.01 g.

Roaches were the only prey that were consistently taken by all of the woodpecker groups (Table 2). Other prey listed in Tables 1 and 2 were frequently collected in large numbers only by a single group. For ex-

TABLE 2
DIFFERENCES IN PROPORTION OF THE 10 MOST COMMON ARTHROPOD PREY AMONG WOODPECKER GROUPS

Prey	Percent of total visits with prey			
	Group 3	Group 18	Group 19	Group 39
Wood roach (*Parcoblatta* sp.)	69.8	63.3	81.6	72.2
Wood borer beetle (larva) (Cerambycidae or Buprestidae)	12.6	1.6	0.0	1.8
Moth (larva) (Lepidoptera)	1.6	9.4	1.9	2.8
Spider (Araneae)	2.3	5.4	2.9	3.0
Ant (larvae and adults) (Formicidae)	3.0	0.2	1.0	7.1
Longhorned grasshopper (*Atlanticus* sp.)	0.0	8.8	0.0	0.0
Centipede (Scolopendromorpha)	1.2	3.7	2.9	3.6
Insect (larva) (Insecta)	2.6	2.8	3.9	2.2
Insect (larvae) (Insecta)	3.0	0.5	0.0	3.0
Beetle (larva) (Coeloptera)	0.8	1.0	0.0	0.8

ample, wood-borer larvae were the second most abundant prey item overall (Table 1). The majority of these were taken by woodpeckers in Group 3 where they made up 12.6% of the visits, while they made up less than 2% of the visits in each of the other groups (Table 2). Similarly, longhorned grasshoppers were utilized only by birds in Group 18. The 55 grasshoppers we observed on the slides were all collected by one bird.

We compared the number of the various prey brought to the nest cavity to the age of the nestlings in the cavity and found no difference in the type of prey fed to young nestlings (e.g., 5–6 days old) versus that fed to older nestlings (e.g., 19–20 days old). Roaches made up the bulk of the diet of nestlings regardless of age. However, we did not have observations for nestlings younger than five days old.

Helper males made fewer visits than either the breeding males or the breeding females (Table 3). For example, the two helper males in Group 19 each made ca. 19% of the visits compared to 35.7% and 26.7% for the breeding male and female, respectively. Breeding females made fewer visits than the breeding males in the three groups with helper males, but

TABLE 3
PROPORTION OF FEEDING VISITS BY RED-COCKADED WOODPECKER BREEDING PAIRS AND HELPER MALES

Group	Bird status	Number of visits	Percent of total visits
3	Breeding male	458	46.2
	Breeding female	378	38.1
	Helper male	156	15.7
19	Breeding male	75	35.7
	Breeding female	56	26.7
	Helper male 1	40	19.0
	Helper male 2	39	18.6
39	Breeding male	341	43.4
	Breeding female	249	31.8
	Helper male	196	24.9
18	Breeding male	400	44.3
	Breeding female	502	55.5

they made more visits than the breeding males in the group that had no helper males.

DISCUSSION

The few studies of prey of Red-cockaded Woodpeckers suggest that they are generalists taking advantage of available arthropods. For example, Red-cockaded Woodpeckers have frequently been reported foraging in corn fields (Ward 1930, Ligon 1970, Baker 1971) where they feed on corn earworms (*Heliothis zea*) and corn leaf aphids (*Rhopalosiphum maidis*) (Baker 1971). Beal (1911) and Beal et al. (1916) analyzed the gut contents of 99 Red-cockaded Woodpeckers taken throughout the year. They reported that ants in the genera *Camponotus* and *Crematogaster* were the most common prey of adult birds, based on numerical counts, but they did not tell which genus was more prevalent or how the birds were collected and handled following collection.

More recent studies have shown that gut content analysis of birds can have limitations resulting from differential rates of prey digestion (Rosenberg and Cooper 1990). For example, Koersvald (1951) showed that in Corvidae the digestion of food continues for some time after bird death. Dillery (1965) compared the content of stomachs of Savannah Sparrows (*Passerculus sandwichensis*) preserved immediately after collection to specimens that received no preservation treatment. He concluded that the results of analysis on stomach contents where digestion was not stopped

can be biased, since hard to digest parts "are like gravel" and can remain in the stomach for sometime, while more easily digested material can disappear within five minutes. Other studies have demonstrated that the digestion rates of arthropods vary among prey items, bird species, and state of bird starvation (Custer and Pitelka 1975, Gartshore et al. 1979, Coleman 1974, Stevenson 1933, Mook and Marshall 1965). Mook and Marshall (1965) concluded that, without a knowledge of the digestion time and the digestion rate of arthropod prey in a given species of bird, it is not possible to use gizzard analysis in a quantitative way. Thus, information on the prey of Red-cockaded Woodpeckers based on stomach analysis (Beal 1911, Beal et al. 1916) probably should be consider qualitative.

Both *Crematogaster* sp. and *Camponotus* sp. construct nests in live trees. We frequently observed *Crematogaster* sp. nesting in the thick outer bark (and occasionally in dead limbs), while *Camponotus* sp. were found nesting in dead branches in the crown of live trees. Although *Camponotus* sp. also nest in dead trees, it is the nests in live trees where they are most likely to be encountered by Red-cockaded Woodpeckers. Ants were the second most abundant prey numerically when one considers that each visit to the nest with ants was with a number of individuals. However, comparison of the biomass of ants and roaches shows that the rankings based on numbers of visits (Tables 1 and 2) provides a relatively accurate picture of the overall value of each group of prey in the diet of the Red-cockaded Woodpecker.

Beal (1911) and Beal et al. (1916) reported that Coleoptera larvae, primarily of wood boring beetles, were found in the stomachs of adult Red-cockaded Woodpeckers. Harlow and Lennartz (1977) grouped all insect larvae into one category, which was their most commonly recorded prey item. Although it is impossible to know which larvae they observed, it is interesting to note that their study site was located on the Francis Marion National Forest, which Price et al. (1991) reported suffering an outbreak of southern pine beetles (*Dendroctonus frontalis*) from 1971 and through 1976 the year of their woodpecker prey study. Therefore, it is likely that woodpeckers had access to an abundance of wood-boring larvae commonly found associated with bark beetle-killed trees.

We found wood borer larvae of the families Cerambycidae or Buprestidae to be the second most abundant prey item overall at the Savannah River Site. These are large insects (3–6 cm long) whose audible feeding makes them relatively easy to find. We did not observe Red-cockaded Woodpeckers removing large amounts of loose bark from dead and dying trees, suggesting that they were not foraging for bark beetles (Scolytidae) or other common insects associated with recently killed trees but that they

were foraging specifically for the wood borer larvae. However, the insects we recorded as "Coleoptera larva," "Coleoptera pupa," and most of the "insect larva" records were likely taken from dying or dead trees or from the dead limbs of live trees, since insect larvae rarely occur in the outer bark of live trees (Hanula and Franzreb, unpubl. data). Table 2 shows that wood borer larvae were important only when they were locally abundant, as they were for Group 3 whose nest cavity was within 200 m of a small cluster of bark beetle-killed trees. Wood borers ranked no higher than seventh in numerical abundance of prey for the other three clusters.

Beal (1911) and Beal et al. (1916) found roaches in adult Red-cockaded Woodpeckers but only in the form of ootheca (egg cases). Conversely, Harlow and Lennartz (1977) reported roaches as the third most abundant item in the diet of nestlings after insect larvae and centipedes. In our study, roaches were present in most of the nest visits. Like many insects, their population may periodically increase followed by periods of scarcity. Whether 1993 was a year of relative roach abundance on our study areas is unknown, but fluctuations in populations may explain why the relative importance of this prey item varies among the studies.

Red-cockaded Woodpeckers used a number of Lepidoptera larvae that we were not able to identify. However, we did photograph five visits in which the adults were carrying coneworm larvae (*Dioryctria* sp.), which are borers found in the cones of several southern softwood species. Hooper and Lennartz (1981) observed both sexes pecking green pine cones and speculated that they were extracting coneworms.

When helper males were present, females made fewer visits than the breeding males. In this respect, our results are consistent with those of Lennartz and Harlow (1979) who found that in five Red-cockaded Woodpeckers groups on the Francis Marion National Forest, breeding males tended to make more visits to feed nestlings than females, regardless of the presence of helpers. They found that when helpers were present, breeding males averaged only 30% of the visits, while breeding females averaged 27%. Males made an average of 59% of the visits and females 41% for three pairs with helpers. Females never contributed more than 50% of the visits. Conversely, in our one instance of a pair without helpers, the female fed the young substantially more often than her mate (55% vs 44%).

Our study demonstrates the feasibility of using still photography for studying Red-cockaded Woodpecker prey selection during the nesting season. It is the first study on this bird to compare the diets of young in individual clusters. Although still photography is not a new technique for studying bird diets (Rosenberg and Cooper 1990), it proved more effective than a comparably priced video camera system (Franzreb and Hanula

1995) or personal observation (Harlow and Lennartz 1977), and the cameras had no observable impact on the adults or nestlings we photographed.

ACKNOWLEDGMENTS

We thank D. White, K. Laves, M. Stacklin, T. Kuntz, and H. Barnhill, for technical assistance, and D. Dwinell (USFS), D. Hamrick, and J. Strawser (Univ. of Georgia, CES) for helpful discussions during the development of the camera system. We also thank R. Conner, T. Sherry, and W. Tschinkel for helpful comments on an early draft of this manuscript. This project was supported by the Dept. of Energy, Savannah River Site, and the USDA Forest Service, Savannah River Forest Station. The mention of trade names in this paper is for the information and convenience of the reader. Such use does not constitute official endorsement or approval by the U.S. Dept. of Agriculture of any product to the exclusion of other products that may be available.

LITERATURE CITED

BAKER, W. W. 1971. Observations of the food habits of the Red-cockaded Woodpecker. Pp. 100–107 *in* The ecology and management of the Red-cockaded Woodpecker: proceedings of a symposium (R. L. Thompson, ed.). Bur. Sport Fisheries and Wildl., U.S. Dept. Int. and Tall Timbers Research Station, Tallahassee, Florida.

BEAL, F. E. L. 1911. Food of the woodpeckers of the United States. USDA Biol. Surv. Bull. 37:1–64.

———, W. L. MCATEE, AND E. R. KALMBACH. 1916. Common birds of the southeastern United States in relation to agriculture. USDA Biol. Surv. Bull. 755:34–35.

COLEMAN, J. D. 1974. Breakdown rates of foods ingested by starlings. J. Wildl. Manage. 38:910–912.

CUSTER, T. W. AND F. A. PITELKA. 1975. Correction factors for digestion rates for prey taken by Snow Buntings (*Plectrophenax nivalis*). Condor 77:210–212.

DILLERY, D. G. 1965. Post-mortem digestion of stomach contents in the Savannah Sparrow. Auk 82:281.

FRANZREB, K. E. AND J. L. HANULA. 1995. Evaluation of photographic devices to determine nestling diets of the endangered Red-cockaded Woodpecker. J. Field Ornithol. (in press).

GARTSHORE, R. G., R. J. BROOKS, J. D. SOMERS, AND F. F. GILBERT. 1979. Temporal change in gullet food passage in penned Red-winged Blackbirds (*Agelaius phoeniceus*): significance for research in feeding ecology. Can. J. Zool. 57:1592–1596.

HARLOW, R. F. AND M. R. LENNARTZ. 1977. Foods of nestling Red-cockaded Woodpeckers in coastal South Carolina. Auk 94:376–377.

HOOPER, R. G. AND M. R. LENNARTZ. 1981. Foraging behavior of the Red-cockaded Woodpecker in South Carolina. Auk 98:321–334.

KNOX, J. N. AND R. R. SHARITZ. 1990. Endangered, threatened and rare vascular flora of the Savannah River Site. Savannah River Site National Environmental Research Park Program, Savannah River Ecology Lab, Aiken, South Carolina.

KOERSVALD, E. VAN. 1951. Difficulties in stomach analysis. Pp. 592–594 *in* Proc. 10th Int. Ornithol. Congr. Uppsala, Sweden.

LENNARTZ, M. L. AND R. F. HARLOW. 1979. The role of parent and helper Red-cockaded Woodpeckers at the nest. Wilson Bull. 91:331–335.

LIGON, J. D. 1970. Behavior and breeding biology of the Red-cockaded Woodpecker. Auk 87:255–278.

MOOK, L. J. AND H. W. MARSHALL. 1965. Digestion of spruce budworm larvae and pupae

in the Olive-backed Thrush, *Hylocichla ustulata swainsoni* (Tschudi). Can. Entomol. 97:1144–1149.

PORTER, M. L. AND R. L. LABISKY. 1986. Home range and foraging habitat of Red-cockaded Woodpeckers in northern Florida. J. Wildl. Manage. 50:239–247.

PRICE, T. L., C. DOGGETT, J. M. PYE, AND T. P. HOLMES. 1991. A history of southern pine beetle outbreaks in the southeastern United States. Georgia For. Comm., Macon, Georgia.

ROSENBERG, K. V. AND R. J. COOPER. 1990. Approaches to avian diet analysis. Pp. 80–90 *in* Avian foraging: theory, methodology and applications. Studies in Avian Biology No. 13 (Morrison, M. L., C. J. Ralph, J. Verner, and J. P. Jehl, Jr. eds.). Cooper Ornithol. Society. San Diego, California.

STEVENSON, J. 1933. Experiments on the digestion of food by birds. Wilson Bull. 45:155–167.

WARD, B. 1930. Red-cockaded Woodpeckers on corn. Bird-Lore 32:127–128.