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FORAGING BEHAVIOR AND NESTLING DIET OF CHESTNUT-BACKED CHICKADEES IN MONTEREY PINE[1]

P. K. KLEINTJES[2] AND D. L. DAHLSTEN
Laboratory of Biological Control, University of California, Berkeley, CA 94720

Abstract. The foraging behavior and nestling diet of Chestnut-backed Chickadees (*Parus rufescens*) was studied during the breeding season (March–May) in a Monterey pine (*Pinus radiata*) plantation, 1991–1992. Adult birds spent 79% (±7.1 SD) of their foraging time on Monterey pine as a result of prey availability. The majority of this time was spent perch gleaning and hang gleaning prey from the outer needles of the upper tree crown. Nestling diet was composed of approximately 43% Monterey pine sawfly larvae (*Acantholyda burkei,* Hymenoptera: Pamphiliidae) and 17% tree camel crickets (*Gammarotettix bilobatus,* Orthoptera: Rhaphidophoridae). Both insects feed upon Monterey pine foliage. Spiders and individual Homoptera, Hemiptera, Coleoptera, Lepidoptera, and Diptera species comprised the remaining 40% of the diet. Monterey pine serves as an important foraging resource for Chestnut-backed Chickadees during the breeding season and may have contributed to the range expansion and population increase of this species in the San Francisco Bay region.

Key words: *Chestnut-backed Chickadees;* Parus rufescens; *Monterey pine; foraging behavior; diet; sawfly larvae; insectivorous bird.*

INTRODUCTION

Changes in native vegetation often influence bird population abundance, distribution and behavior (Dixon 1954, DeGraaf and Wentworth 1981, Morrison and Keane 1988, Brennan and Morrison 1991). In the San Francisco Bay region, the recent range expansion and population increase of Chestnut-backed Chickadees has been attributed to the conversion of native oak woodland and grasslands to orchards and urban landscapes (Dixon 1954, Brennan and Morrison 1991).

The Chestnut-backed Chickadee is usually associated with moist coniferous forests of the Pacific Coast and more recently, montane forests containing Douglas-fir (Grinnell 1904, Brennan and Morrison 1991). Therefore, we presume that planting of conifers, particularly stands of Monterey pine (*Pinus radiata*), has contributed to the birds' successful invasion of the San Francisco East Bay region.

Monterey pine is native to central coastal California, but has been widely planted as an "ornamental" in urban landscapes, recreation areas and Christmas tree plantations (Barbour and Major 1988). Chestnut-backed Chickadees are known to breed in Monterey pine plantations and in many areas, coastal populations of Chestnut-backed Chickadees overlap the distribution of both native and planted Monterey pine (Grinnell 1904, Brennan and Morrison 1991, Kleintjes and Dahlsten 1992).

The foraging behavior of Chestnut-backed Chickadees has been well documented in the coastal live oak and mixed evergreen woodlands of the California Coast Ranges (Dixon 1954, Root 1964, Rowlett 1972, Hertz et al. 1976, Wagner 1981) and the mixed coniferous forests of both the Pacific Northwest (Sturman 1968, Lundquist and Manuwal 1990) and Sierra Nevada (Brennan 1989, Brennan and Morrison 1990). However, little is known about their foraging behavior in Monterey pine stands, nor about their insectivorous diet (Dixon 1954, Kleintjes and Dahlsten 1992).

The purpose of this study was to determine the importance of Monterey pine for breeding Chestnut-backed Chickadees, as part of long term studies on the breeding biology of Chestnut-backed Chickadees nesting in artificial nestboxes in the San Francisco East Bay region and Sierra Nevada of California (Gold and Dahlsten 1989; Kleintjes and Dahlsten 1992; Dahlsten, unpubl. data).

Our objectives were to evaluate the use of Monterey pine by determining: (1) the foraging behavior of adult Chestnut-backed Chickadees

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[2] Present address: Department of Biology, University of Wisconsin, Eau Claire, WI 54702.

in a Monterey pine plantation and (2) the abundance and composition of Monterey pine feeding insects in the diet of Chestnut-backed Chickadee nestlings.

METHODS

STUDY AREA

The study was conducted on the northeastern slope of the Berkeley Hills in the East Bay Municipal Utilities District, Contra Costa County, California, during March–May, 1988–1992. Fifty-three nestboxes were established in the area during 1978 (Gold and Dahlsten 1989). They were placed along a series of trails at intervals of 25–50 m, 1.5 m above the ground. The nestboxes were constructed of sawdust and cement and contain a removable front (Schwegler and Sons, Munich, Germany).

The study area encompassed mature stands of planted Monterey Pine that were adjacent to stands of mature coast live oak (*Quercus agrifolia*) woodland. Understory vegetation consisted of poison oak (*Toxicodendron diversilobum*), blackberry (*Rubus ursinus*) and regenerating coast live oak, California bay laurel (*Umbellaria californica*) and elderberry (*Sambucus mexicana*) (Kleintjes and Dahlsten 1992). Relative density of tree species was determined by a plotless point-center-quarter method (Cottam and Curtis 1956). A row of twenty-five nestboxes (25–50 m apart) within a 15 ha^2 area served as sampling points. Relative density of Monterey pine was 76%, Monterey pine snags (12%), California bay laurel (7%) and coast live oak (5%).

FORAGING BEHAVIOR

Foraging was observed during 1 April–31 May, 1990, 3 April–31 May, 1991 and 10 March–15 May, 1992. We standardized collection of observations to between 06:00–12:00 hrs, three to five times per week while walking a 3.2 km trail through the plot. At the first sighting of a bird, we waited to avoid recording conspicious behaviors. Immediately thereafter, the first foraging observation was recorded. The observer then moved a minimum distance of 50 m between each individual bird to increase the independency among observations made on the same day. We used foraging variables modified from Remsen and Robinson (1990) to describe each observation: bird height within tree (meters and one-third levels of crown); foraging distance from bole (inner, middle and outer one-third of crown); foraging substrate (needle, small twigs, bark, leaves and cones); tree species (Monterey pine, coast live oak, California bay laurel, elderberry, and willow *Salix* sp.); date and time of day; weather and sex (if color band was visible). In addition, we recorded the following foraging activities: (1) perch-gleaning (picking food from the substrate when perched); (2) hang gleaning (picking food from the substrate while hanging upside down); (3) hover gleaning (picking food from the substrate while hovering); (4) pecking (driving bill against substrate to remove food); (5) probing (inserting bill into substrate to remove hidden food) and (6) other. We collected at least 40 observations per breeding season, as recommended by Brennan and Morrison (1990) for the Chestnut-backed Chickadee in the central Sierra Nevada.

Frequencies of behaviors were compared between years with contingency tests (Likelihood Ratio Chi-square, $P < 0.05$). Separate tests were used for vertical location, horizontal location, activity, substrate and tree species. Each test contained an "other" category which contained the sum of the variables whose individuals frequencies were less than 5. Because there was no significant difference between years for any of the variables, except for tree height, the 1991–1992 foraging data were pooled across years.

PHOTOGRAPHY AND FECAL SAC ANALYSIS

Photography and fecal sac analysis were used to determine nestling diet composition. In an earlier study, we found photography to provide the most detailed information on nestling diet (Kleintjes and Dahlsten 1992). However, mechanical problems with cameras can cause gaps in data collection and limit sample size. Therefore, we used fecal analysis to provide supplemental information and to serve as a safety for camera failures.

Photographs were obtained with an 8 mm movie camera attached to the back of occupied nest boxes (Dahlsten and Copper 1979). A camera unit was used in place of an original nestbox from the time nestlings were eight days old until fledging.

A total of 561.5 hr of film from six Chestnut-backed Chickadee nests was recorded in 1989–1992. In 1989, we obtained film from two nests, boxes number 34 and 36. We excluded box 36

from analysis because the nestlings were reared by one adult and their number decreased from five to two nestlings during filming. In 1990 and 1991 we obtained film from one nest each year and in 1992, we obtained film from two nests. Parents of all nests were recorded bringing in prey on average 14 hr a day from 06:00 hr to 20:00 hr. Diet information was based on nestlings that were typically 10–20 days old and were raised in broods of 5–7 nestlings.

We reviewed film under 25× magnification to identify prey items. Prey items were counted according to the number and category brought in each trip every hour, each foraging day. Each nest box was considered equivalent to one sample. Percent abundance of each prey category was calculated for each nest from the total number of prey delivered to the nest during the entire filming period (10 days). For statistical analysis, we pooled the data from the five nests (approximately 450 hr) to calculate the mean percentage of each prey category delivered to the 10–20 day old nestlings. Percentages were modified with a square root transformation because the range of percentages did not lie between 30–70% (Sokal and Rohlf 1981). Means and variances for each prey category were compared with a standard one-way analysis of variance (ANOVA) for equal sample sizes (Zar 1984). The Tukey's HSD method was used for pairwise comparisons (Zar 1984).

Fresh fecal sacs were collected from young during box checks (twice per week) and banding (see Kleintjes and Dahlsten 1992). Each sac was placed in a small plastic vial and frozen within 3 hr of collection. Samples were collected at variable times and dates throughout each nesting season from a minimum of three nests and a minimum of 24 hr between collections from the same nest. Fecal sacs were collected from as many nests as possible when nestlings were 9–20 days old. An explanation of sample size estimates and analysis of sac contents is described in Kleintjes and Dahlsten (1992). Forty-five nestling fecal sacs were collected during three breeding seasons; 12 fecal sacs from four nests during 13–29 April 1988, eight sacs from four nests during 13–23 May 1989 and 25 sacs from five nests during 8–28 May and 4 June 1991. Data from all fecal sacs were pooled to calculate the mean percentage of each prey category delivered to the nests. Percentages represented the proportion of prey that remained intact through the digestive process.

RESULTS

FORAGING BEHAVIOR

Chestnut-backed Chickadees spent the greatest percentage of their foraging time on Monterey pine (79.2% ± 7.1 SD) (Fig. 1). Approximately 16% of their time was spent on coast live oak, although oak comprised only 5% of the relative tree density in the study area.

The greatest proportion of substrate use was spent on needles (63.6% ± 4.2 SD) followed by use of leaves on evergreen and deciduous trees (18.7 ± 9.9 SD) (Fig. 1). The birds used perch and hang gleaning behaviors more than any other activity and spent a greater frequency of time in the outer, upper crown (Fig. 1). The mean foraging height of the birds in Monterey pine, 1991–1992 was 13.7 m (±0.84 SD). The mean height of pine used in 1991 was 25.3 m (±5.8 SD) and 22.86 m (±4.3 SD) in 1992. Tree height significantly differed between years (*t*-test, $P < 0.05$).

NESTLING DIET COMPOSITION

From photographic records, 8,222 prey were identified from a total of 9,514 items brought to the nests. The Monterey pine sawfly (*Acantholyda burkei*) (Hymenoptera: Pamphiliidae) comprised the significantly largest mean percentage (43%) of total prey in the nestling diet ($F = 17.38$, $P < 0.05$, one-way ANOVA) (Table 1). The tree camel cricket (*Gammarotettix bilobatus*) (Orthoptera: Rhaphidophoridae) comprised 17% of total prey. All other identifiable prey items comprised 25% of the diet, whereas unknown prey items comprised 14% (Table 1). When identified prey were grouped into one of eight orders, the Hymenoptera comprised the greatest percentage of prey items (51.2%), followed by Orthoptera (19.8%), Lepidoptera (8.0%), Homoptera (6.5%), Hemiptera (5.8%), Arachnids (5.0%), Diptera (3.5%), and Coleoptera (0.1%) (Fig. 2).

Records from fecal analysis indicated that 86 prey items were present and identifiable to insect Order or as an Arachnid. The greatest percentage of identified prey belonged to the order Hymenoptera (30.8%), followed by Orthoptera (22.1%), Homoptera (16.1%), Lepidoptera (14.0%), Arachnids (9.3%), Hemiptera (3.3%), Coleoptera (2.6%) and Diptera (1.3%) (Fig. 2). The remaining contents were uncounted fragments of exoskeleton, leg segments, eggs, setae, spiracles, vegetable material and pebbles. Photography and

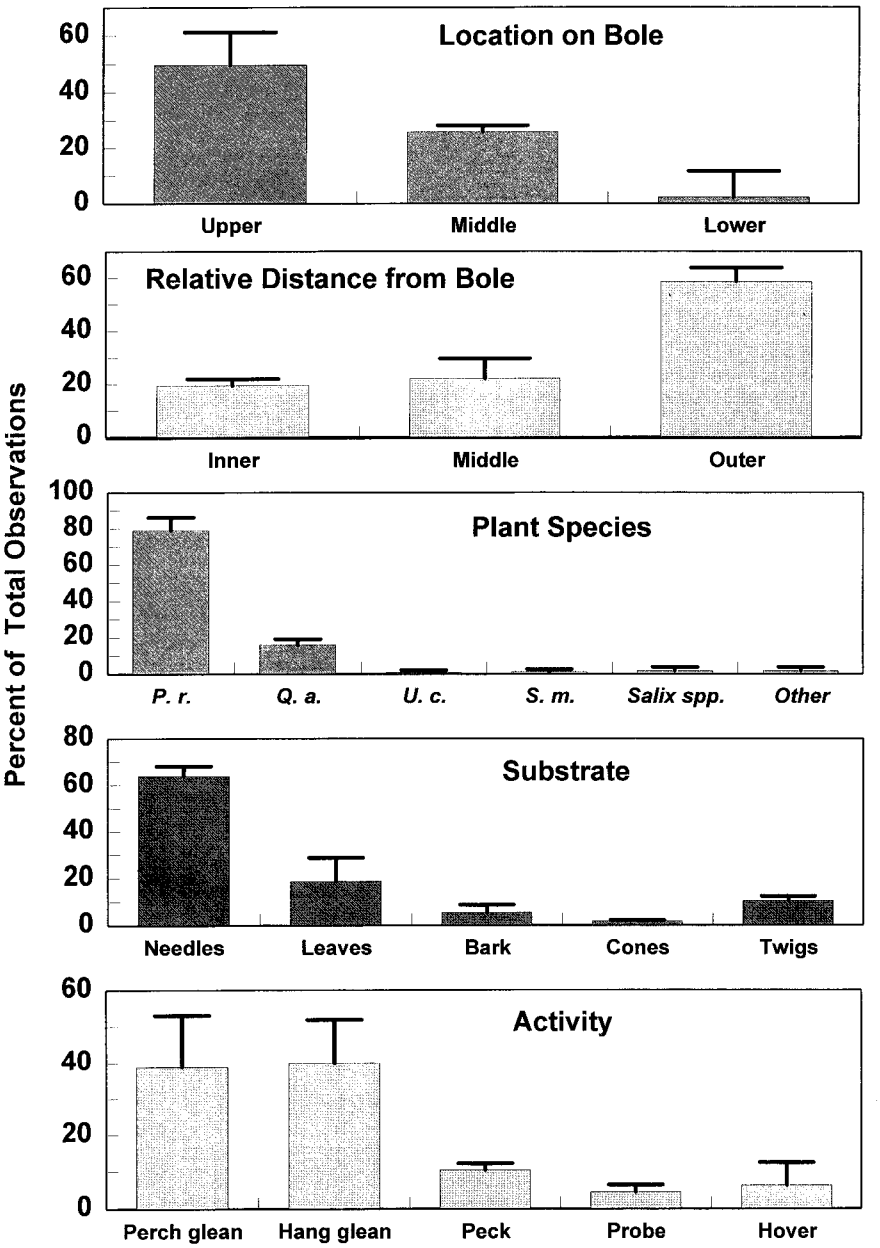

FIGURE 1. Foraging behavior of Chestnut-backed Chickadees (*Parus rufescens*) in a Monterey pine (*Pinus radiata*) plantation, as a percent of total observations collected during the breeding season, Contra Costa Co., California, 1991 ($n = 66$) and 1992 ($n = 51$). Tree species are *P. radiata* (*P.r.*), *Quercus agrifolia* (*Q.a.*), *Sambucus mexicana* (*S.m.*), *Salix* spp. and *Umbellularia californica* (*U.c.*).

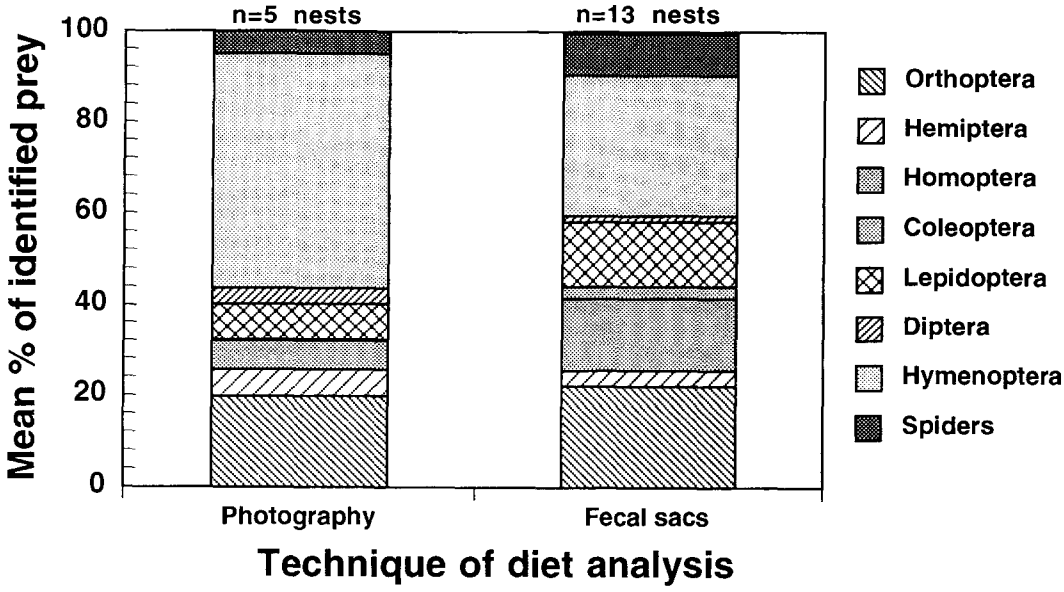

FIGURE 2. Mean proportion of insect Orders and spiders in the diet of Chestnut-backed Chickadee (*Parus rufescens*) nestlings in a Monterey pine (*Pinus radiata*) plantation, Contra Costa County, California, 1989–1992.

fecal sac analysis were not statistically compared due to different levels of precision.

DISCUSSION

Our results indicate that Monterey pine is an adequate foraging resource for Chestnut-backed Chickadees in the San Francisco Bay region during the breeding season. In a stand composed of approximately 75% Monterey pine trees, Chestnut-backed Chickadees spent nearly 80% of all foraging observations on the pines. In addition, nearly 80% of the nestling diet was composed of insects found on Monterey pine foliage.

Previous studies of the foraging behavior of Chestnut-backed Chickadees in coast live oak and mixed-evergreen woodlands of the San Francisco East Bay indicate differing preferences for native plant species during the breeding season. Dixon (1954) found Chestnut-backed Chickadees spent the greatest percentage of their foraging time on coast live oak whereas, Root (1964) found Chestnut-backed Chickadees spent nearly equal amounts of foraging time on California bay laurel, coast live oak and madrone (*Arbutus menziesii*). Even though some of these species were available on and near our study area we found Chestnut-backed Chickadees spent the majority of their foraging time on Monterey pine. We acknowledge that our provision of artificial nesting sites in the pine stand increased the likelihood of Chestnut-backed Chickadees using and breeding in the area. However, it is apparent from our results that availability of prey on Monterey pine during the breeding season caused the birds to spend a greater amount of time foraging on the pines and delivering pine-feeding insects to their young. Sturman (1968) and Brennan (1989) also found that Chestnut-backed Chickadees preferred to forage on coniferous trees during the breeding season although species of evergreen and deciduous hardwoods were available.

Our results support earlier observations of the Chestnut-backed Chickadees preference for foraging on outer foliage (needles, leaves or buds) during the breeding season (Dixon 1954, Hertz et al. 1976, Sturman 1968, Brennan 1989). We also found that the birds spent the greatest proportion of their foraging activity hang gleaning and perch gleaning prey from Monterey pine needles. This was not unexpected as the majority of prey in the nestling diet were needle feeding insects, particularly the larvae of the Monterey pine sawfly. In the Central Sierra, Brennan (1989) also found the gleaning behavior of the Chestnut-backed Chickadee to be most common during the breeding season which he associated with an

TABLE 1. Mean percentage of total prey delivered to Chestnut-backed Chickadee (*Parus rufescens*) nestlings in a Monterey pine (*Pinus radiata*) plantation, Contra Costa County, California. Diet was recorded with super 8mm movie cameras (n = 5 nests).

Prey	$\bar{x}$ % (±SD)
Orthoptera	
Rhaphidophoridae (*Gammarotettitix bilobatus*)	17.0 (11.7)
Hemiptera	
Reduviidae (*Zelus cervicalis*)	4.9 (3.6)
Homoptera	
Cercopidae (*Aphrophora* sp.)	3.9 (4.2)
Cicadidae	0.91 (0.68)
Aphididae	0.47 (0.85)
Coleoptera	0.12 (0.2)
Lepidoptera	
Larvae	4.4 (4.3)
Adults	2.8 (2.8)
Diptera	
Tipulidae	0.83 (1.4)
Syrphidae	0.69 (0.88)
Tabanidae	1.4 (1.6)
Hymenoptera	
Pamphiliidae (*Acantholyda burkei*)	42.6 (18.3)
Arachnidae	4.3 (3.3)
Pupae	1.1 (1.0)
Unknown	14.5 (4.7)

increased abundance of foliage feeding arthropods.

Although photography and fecal analysis of nestling diet could not be statistically compared, proportions of prey in the diet were similar. Both methods indicated that Hymenoptera and Orthoptera composed the greatest percentage of identifiable prey items.

The most abundant prey in the nestling diet were Monterey pine sawfly larvae. These larvae are solitary webspinners and feed among the outer branches of Monterey pine within a silken web covered with frass and needle pieces (Burke 1929). Occasionally, adult chickadees also brought adult sawflies to the nestlings. The only previous observation of avian predation upon Monterey pine sawflies was recorded in Monterey County, California, by Burke (1929).

It is notable that webspinning sawflies are also an important food source for other conifer-gleaning insectivorous birds. Different species of *Acantholyda* larvae have been found in the diet of nestling Mountain Chickadees in northern California (Grundel and Dahlsten 1991) as well as in the diets of various European parids (Tinbergen 1960).

Tree camel crickets were the second most abundant prey in the nestling diet of Chestnut-backed Chickadees. These insects are generalist herbivores of trees and shrubs in the coast live oak woodlands of California (Essig 1926). The crickets have not been previously recorded from Monterey pine, although during random beating and visual examination of lower crown Monterey pine foliage, we commonly observed crickets throughout the nestling period (pers. observ.). They were also observed on coast live oak foliage which may have partially accounted for the birds' greater proportion of foraging time (15%) on coast live oak while the density of oaks was low (5%). The birds also brought in numbers of reduviids and cercopid nymphs. Both have been collected on Monterey pine (Ohmart 1981).

Because we found Monterey pine served as a major food resource for breeding Chestnut-backed Chickadees, we believe the extensive planting of Monterey pine and other conifers has probably contributed to the successful establishment and continued increase of Chestnut-back Chickadees in the San Francisco Bay region (Dixon 1954, Brennan and Morrison 1991). Although chickadees forage in coastal live oak woodlands, it appears that when Monterey pine is planted in close proximity to or in replacement of oaks, the pines provide additional foraging habitat. This is particularly true with regards to the availability of webspinning sawflies and tree camel crickets during the breeding season. Not only did these insects influence chickadee foraging behavior but their abundance in the diet potentially contributed to the birds' reproductive success. To further understand the reasons behind the successful range expansion of Chestnut-backed Chickadees, it would be of great interest to study their foraging behavior and diet in a number of habitats, particularly in Monterey pine stands and adjacent coast live oak and mixed-evergreen woodlands during the breeding and non-breeding seasons.

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