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Home Range and Habitat Preferences of the Banded Ground-cuckoo (*Neomorphus radiolosus*)

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ABSTRACT.—The Banded Ground-cuckoo (*Neomorphus radiolosus*) is a rare, endangered, and poorly known species endemic to the Chocó Biogeographic Zone. We summarize 7 months of data from radio tracking an adult in northwestern Ecuador. Home range estimates were 42.2 ha (minimum convex polygon) and 49.9 ha (95% kernel analysis); the core area was 3.4 ha (50% kernel analysis). The bird favored undisturbed habitat and avoided secondary forest. It was primarily insectivorous and rarely associated with army ants (*Eciton* sp.) and not with mammals. Breeding occurred from March through June and the marked bird was seen with an unmarked individual throughout the study. The Banded Ground-cuckoo has a large home range, limited dispersal ability, and apparently depends on undisturbed forest. Deforestation and habitat fragmentation appear to be the gravest threats facing the species. *Received 15 December 2006. Accepted 28 April 2007.*

Ground-cuckoos (*Neomorphus*: Cuculidae) are terrestrial, rain-forest-dwelling birds distributed across the Neotropics (Haffer 1977, Payne 1997). They forage on insects, small vertebrates, and fruit often while associating with army ants (*Eciton* sp.), *Tayassu* peccaries, or *Saimiri*, *Cebus*, and *Saguinas* primates (Sick 1949, Willis and Oniki 1978, Willis 1982, Terborgh 1983, Siegal et al. 1989). Biparental care has been reported for one species (Karubian et al. 2007), and none is thought to be a brood parasite (Sick 1949, Haffer 1977, Roth 1981, Payne 1997). Little else is known about any of the four species of *Neomorphus*, which replace each other geographically.

The Banded Ground-cuckoo (*Neomorphus radiolosus*) is endemic to the Chocó rain forests of northwestern Ecuador and western Colombia. It is one of the rarest birds in either country; in recent years it has been reported from only two localities in Ecuador (Hornbuckle 1997, López-Lanús et al. 1999, Ridgely and Greenfield 2001) and three localities in Colombia (Payne 1997). It is considered ''vulnerable to extinction'' because of widespread deforestation throughout its range, but a lack of data on habitat requirements, home range, and other basic ecological parameters has hindered assessment of its conservation requirements and status (BirdLife International 2000, Greenfield 2002, Renjifo et al. 2002). We report observations on the home range and habitat use of the Banded Ground-cuckoo based on a 7-month radio-tracking study of an adult in northwestern Ecuador.

METHODS

Our study was conducted at Bilsa Biological Station (79° 45′ W, 0° 22′ N, 330–730 m elevation), a 3,500-ha private reserve within the Mache-Chindul Ecological Reserve in Esmeraldas Province, Ecuador. Bilsa is mostly undisturbed forest but also contains selectively-logged and regenerating forests. The surrounding area is largely deforested but also contains selectively logged and regenerating forests.

We captured an adult Banded Ground-cuckoo in a mist net in December 2002, obtained standard morphological measures, and applied three colored leg bands. We also attached a radio transmitter (model RI-2C, Holohil Systems, Carp, ON, Canada) using a backpack style harness of thin rubber ligature (Vehrencamp and Halpenny 1981). The 6.0-g radio weighed 1.4% of the bird's total body mass of 433 g. Total processing time was 43 min. We tracked the bird over a period of 210 days (until the radio failed) using a Telonics TR4 receiver and a RA-2AK ''H'' antenna.

We attempted to record a single fix of the bird's location during each radio-tracking session when we first observed the bird or when

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we heard a vocalization in combination with a radio signal that indicated the distance between the bird and the researcher was <20 m. We recorded only one fix per day to ensure independence of points. We recorded 53 fixes, 22 (42%) after observing the bird and 31 (58%) after hearing it. We recorded a single fix at each of two nests but suspended radio tracking during nesting to minimize disturbance. We recorded UTM coordinates at each fix using a Garmin GPS and plotted the coordinates using the Animal Movement Analysis extension in ArcView Geographical Information System (Hooge and Eichenlaub 2000). Fixes were visualized as minimum convex polygons (MCP's) (Mohr 1947), and 95% and 50% fixed kernel isopleths using least-squares cross validation (Worton 1989, Seamann and Powell 1996). MCPs are included despite their inherent biases (Powell 2000) to allow comparison with other studies. We recorded the presence or absence of army ants and mammals at radio points and opportunistically recorded social behavior and foraging. We assessed habitat characteristics at 48 fixes using 10-m radius circular plots which were compared to 10-m radius circular control plots of known history (primary forest, selectively-logged forest, and secondary forest regenerating 12–20 years). We estimated canopy height and number of trees in the genera *Cecropia* (Cecropiaceae) and *Miconia* (Melastomataceae) in each circular plot. Both are pioneer tree species that can be used as an index of habitat disturbance. We counted number of trees with a diameter at breast height (dbh) >50 cm in circular plots of 20 m.

We mist netted a second adult on 4 May 2005 near a nest in incubation stage and attached a 6.0-g Holohil RI-2C radio transmitter (1.6% of the bird's body mass of 365 g) with a backpack style harness. Total processing time was 38 min. We used radio tracking and visual observation to confirm this bird resumed normal incubation that same afternoon and continued through 7 May. On 4 June 2005 we discovered the remains of this bird (bones, most of which had been fractured, and feathers scattered over 3 m^2) 420 m from point of capture. We recovered the radio 3 m from the remains. The broken bones and damage to the radio suggest predation by a mammal. We did not obtain any radio points for this bird.

We present data as means ± SE. We analyzed habitat data with pairwise Wilcoxon signed rank tests using $P < 0.05$ as the significance level because the data were not normally distributed. Analyses were conducted using JMP (SAS 2003).

RESULTS

We obtained 53 independent fixes between 5 December 2004 and 7 July 2005. The MCP and kernel analysis home range sizes were, respectively, 42.2 ha and 49.9 ha (Fig. 1). The core use area was 3.4 ha (Fig. 1). Vegetation at fixes differed ($P < 0.05$) from plots in secondary forest in all four parameters considered (Table 1) and from plots in selectively-logged forest in two parameters, but did not differ from primary forest plots in any parameter.

The bird was observed with army ants on five occasions (9.5% of all fixes) but not with mammals. We observed the bird eat seven insects (4 grasshoppers, 3 unknown) that it flushed up and pursued as would a Roadrunner (*Geococcyx* spp.). On one occasion the bird appeared to eat decaying pulp (no larvae were present) of a fallen *Gustavia dodsonii* (Lecythidaceae) seed. Excluding observations at active nests, the radio-equipped bird was seen or heard with another adult Banded Ground-cuckoo on seven occasions (13.2% of fixes) evenly distributed throughout the study period.

Morphological measures for the first and second radio-equipped birds, respectively, were tarsus (73.8 and 77.1 mm), wing chord (150 and 156 mm), tail length (250 and 254 mm), bill depth (19.6 and 16.7 mm), bill width (13.8 and 13.8 mm), culmen from the distal edge of the nare (33.8 and 35.1 mm), and exposed culmen (58.1 and 58.0 mm). The gender of both birds was unclear. The first radio-equipped bird was lightly molting on the body and remiges, and the second bird was heavily molting on the body and remiges, and had an active brood patch.

DISCUSSION

This is the first report of home range size for any Neomorphinae, a sub-family of cuckoos with five New World genera including the Ground-cuckoos and Roadrunners. The Banded Ground-cuckoo's home range of ~50 ha, a

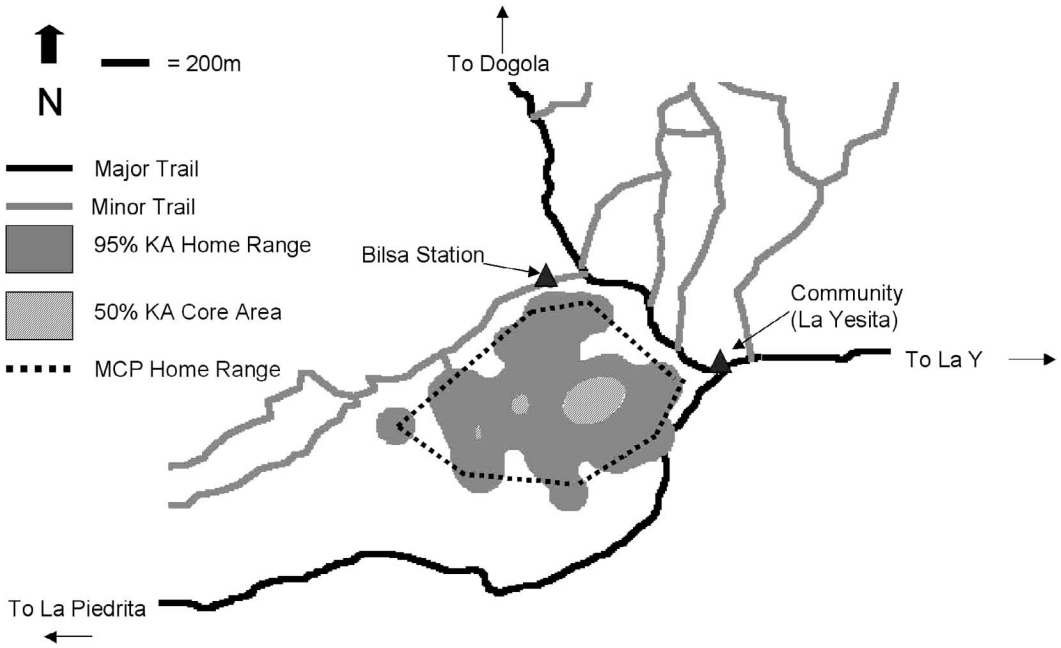

FIG. 1. Minimum convex polygon (MCP) home range and Kernel analysis (KA) home range and core use area of an adult Banded Ground-cuckoo during 7 months in Bilsa Reserve, northwestern Ecuador.

conservative measure because of the study's limited duration, is large relative to other terrestrial rain forest species. Mountain Wood Quail (*Odontophorus hyperythrus*, 275 g) in the Colombian Andes had home ranges of 5.2 ha (Franco et al. 2006) and Chowchilla (*Orthonyx spaldingii*, 150 g) in the Australian Wet Tropics had home ranges of <2 ha (Jansen 1999).

Banded Ground-cuckoos are cryptic, difficult to observe, unlikely to be captured in mist nets, and do not reliably respond to playback, making censuses using traditional methods unreliable. However, local population size can be estimated with home range data. Assuming Bilsa contains 2,000 ha of suitable habitat (e.g., primary forest; Jatun Sacha Foundation, unpubl. data) and the species forms socially monogamous pairs with 50-ha territories, Bilsa could contain ~40 pairs. This emphasizes the reserve's importance for this and other endemics given the widespread deforestation in the Chocó (Sierra 1999, Conservation International 2001).

Army ants are common at Bilsa and the Banded Ground-cuckoo occasionally associated with them (9.5% of fixes) but was not an obligate or even frequent army ant follower as has been previously suggested (Willis and Oniki 1978, Willis 1982, Ridgely and Greenfield 2001). It did not associate with mammals, although this may be due to the rarity of pec-

TABLE 1. Habitat characteristics at Banded Ground-cuckoo radio fix locations versus control plots.

Plot type	Canopy ht. (m)	Trees >50 cm dbh	*Miconia*	*Cecropia*
Radio fixes (n = 48)	23.27 ± 0.94	4.31 ± 0.36	0.64 ± 0.16	0.79 ± 0.26
Control (n = 170)				
Primary (n = 98)	25.26 ± 0.42^{NS}	5.08 ± 0.26^{NS}	0.42 ± 0.15^{NS}	0.48 ± 0.14^{NS}
Selectively-logged (n = 34)	22.38 ± 0.90^{NS}	3.79 ± 0.58^{NS}	1.79 ± 0.42*	2.88 ± 0.68***
Secondary (n = 38)	15.42 ± 1.04***	1.18 ± 0.20***	2.94 ± 0.80**	4.34 ± 0.98***

* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; ^{NS} = $P > 0.05$.

caries and primates within its home range (JK, unpubl. data). Our observations here in combination with a previous study of the species' nesting biology (Karubian et al. 2007) suggest that large insects and small vertebrates are an important part of the diet. The Banded Ground-cuckoo, as a terrestrial omnivore that primarily captures rapid live prey, fills an unusual ecological niche among neotropical rain forest birds, which may be reflected in its large home range.

The radio-equipped bird was with another adult at least seven times from December into May. The adults maintained vocal but not visual contact when together and often foraged >20 m apart. Breeding extended from March into May and birds exhibited bi-parental care at the nest (Karubian et al. 2007). López-Lanús et al. (1999) recorded an apparent juvenile at Bilsa in February 1997, suggesting the breeding season may begin earlier. The color-banded bird that we radio-tracked in the present study was repeatedly observed in April 2007 close to the 2005 nest sites.

The home range contained a mosaic of habitat types including ~25% secondary forest, but the Banded Ground-cuckoo showed a strong preference for undisturbed forest. Two nesting attempts and care of a newly fledged chick also occurred in primary forest (Karubian et al. 2007). This suggests dependence on primary forest both for nesting and foraging, and corroborates previous assessments of the species' conservation requirements (BirdLife International 2000, Greenfield 2002, Renjifo et al. 2002). Deforestation and fragmentation appear to be the primary threats to the Banded Ground-cuckoo; protection of the remaining primary Chocó rainforest should be high priority for conservation of this species. Other factors contributing to the species' vulnerability may include its relatively large home range, low density, presumably poor dispersal ability, and apparent clutch size of one egg (Karubian et al. 2007).

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Comparisons between Juvenile and Adult American Robins Foraging for Mulberry Fruit

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ABSTRACT.—American Robins (*Turdus migratorius*) depend on fruit in fall and winter and, accordingly, juvenile robins must quickly learn to acquire this resource. We compared the foraging abilities of juveniles and adults foraging for mulberries (*Morus* spp.), the first fruit that ripens after juveniles have become independent. Juveniles were significantly less successful than adults at obtaining mulberries; 23% of juveniles' attempts to remove fruit were successful compared to 69% of attempts by adults to remove fruit. As a result, juveniles consumed 0.4 mulberries/min whereas adults consumed 2.8 mulberries/min. Further investigations of juveniles' ability to forage for fruit are needed to understand the mechanisms involved in the development of skills to forage for this vital resource. *Received 20 February 2007. Accepted 17 June 2007.*

Foraging for fruit is often assumed to be an easily acquired skill, unlike foraging for animal prey (Stevens 1985, Desrochers 1992, Ricklefs 2004). Support for this assumption regarding avian fruit foraging, however, is mixed. Analyses of stomach contents at times show that juveniles consume more fruit than adults, which suggests that fruits are relatively easily obtained (Wheelwright 1986, Eggers 2000). In addition, some studies found no differences in foraging behavior or rates of fruit consumption between juveniles and adults (European Robin [*Erithacus rubecula*], Common Blackbird [*Turdus merula*], Eurasian

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Blackcap [*Sylvia atricapilla*]; Hampe 2001, Bas et al. 2006). However, juveniles often consume different types of fruits than adults, which could be a result of differences in foraging abilities (Boddy 1991), and tests of skill level and acquisition of skill have yet to be thoroughly conducted.

If juveniles are less skilled at foraging for fruit, their lower proficiency could be costly, especially for individuals of the many species that depend on fruit for migration and overwintering (Willson 1986, Blake and Loiselle 1992, Levey and del Rio 2001, McCarty et al. 2002, Heise and Moore 2003, Kwit et al. 2004). Juvenile birds often have lower survival rates than adults and starvation is a major cause of juvenile mortality (Sullivan 1988, Catterall et al. 1989, Donnelly and Sullivan 1998). Accordingly, juveniles of migratory species and those that have high mortality should be expected to develop their fruit-foraging skills quickly.

One species that relies heavily on fruit for migration and overwintering is the American Robin (*Turdus migratorius*). The diet of the robin is composed primarily of fruit from late summer through winter (Wheelwright 1986). We compared foraging rates on mulberry fruit (*Morus* spp.) to investigate whether juveniles were less successful at foraging on fruit than adults. Mulberry is the first tree to fruit after juveniles begin to forage independently at our study site in Louisville, Kentucky. Accordingly, we were able to compare naïve juveniles to experienced adults in their ability to forage on this fruit. Our specific objectives were to: (1) quantify and note differences in the outcome of mulberry foraging bouts by juveniles and adults and (2) examine whether or not juveniles and adults differ in their rates of successful and failed attempts to pick mulberries.

METHODS

We investigated juvenile and adult robins' ability to forage for mulberry fruit from 25 May until 23 June 2006 at Joe Creason Park in Louisville, Kentucky (38° 12′ N, 85° 42′ W). Both adult and juvenile robins foraged in fruiting trees simultaneously at our field site and there was little apparent competition between age groups. We conducted continuous focal scans on 64 American Robins (38 adult scans and 26 juvenile scans) foraging for mulberries on trees scattered throughout the 27.5-ha park. Robins typically flew into the trees, ate fruit, and left relatively quickly; therefore, each scan started when a focal bird entered a mulberry tree and ended when it left the tree or was no longer visible. Samples ranged in length from 10 to 243 sec with the average scan lasting a little over a minute (mean ± SE = 67 ± 5.5 sec).

We recorded four behaviors to assess the ability of juveniles and adults to forage for mulberries. First, when a robin unsuccessfully tried to pick a mulberry, we categorized it as a failure. Typically, a failure resulted when a robin was either unable to reach a fruit or unable to pull sufficiently hard to detach the mulberry. Second, when a robin successfully picked and ate a whole mulberry we recorded it as an 'eat'. Third, because each mulberry is composed of multiple drupelets, robins at times picked and ate only a part of one mulberry; we recorded this as 'piece'. Finally, if a robin picked a fruit, but subsequently dropped it, we called it a 'drop'.

We calculated percent success (number of eats/total attempted picks) and percent failure (number of fails/total attempted picks) for each adult and juvenile scan, and compared adult and juvenile scans using a MANOVA followed by individual ANOVAs. We also calculated fruit capture rate (number of eats/min) and fruit failure rate (number of failures/min) for all scans, and compared juvenile scans and adult scans using a MANOVA and follow-up ANOVAs. Fruit failure rate was transformed to meet MANOVA assumptions as follows: transformed fruit failure rate = 1/(1 + failure rate). Few robins dropped fruit and robins seldom picked only a piece of the mulberry. The piece and drop data did not meet MANOVA assumptions, and could not be successfully transformed. We excluded these data from the MANOVA analyses and instead used two Fisher's exact tests to examine whether a greater proportion of juveniles engaged in these behaviors than adults. Means ± SE are reported from non-transformed data and SAS© (2003) was used for all statistics.

RESULTS

Juvenile American Robins were significantly less skilled at obtaining mulberries than

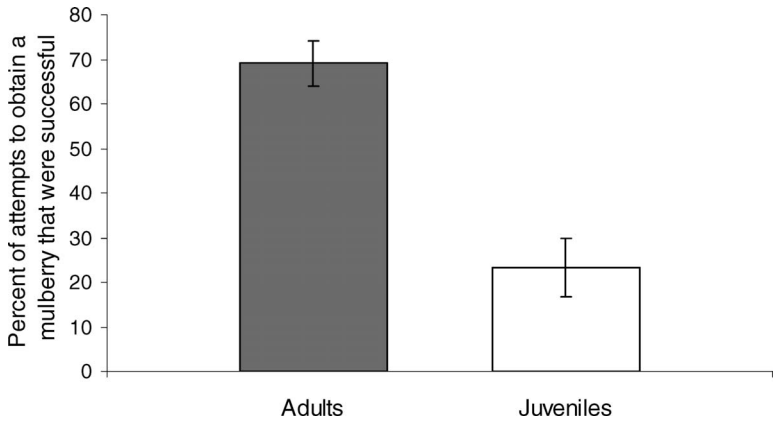

FIG. 1. Juvenile vs. adult American Robins' success at obtaining mulberries.

adults (MANOVA: Wilks' Lambda $F_{2,59} = 15.27$, $P < 0.001$); only 23 ± 6.4% of attempts to pick mulberries by juveniles were successful compared to 69 ± 5.2% for adults (ANOVA: $F_{1,60} = 29.55$, $P < 0.001$; Fig. 1). In addition, a significantly larger percentage of attempts by juveniles ended in failure (ANOVA: $F_{1,60} = 25.41$, $P < 0.001$; juvenile mean = 64 ± 6.7%, adult mean = 23 ± 4.6%). Foraging rates were also significantly different between juveniles and adults (MANOVA: Wilks' Lambda $F_{2,61} = 24.74$, $P < 0.001$). Juveniles consumed significantly fewer mulberries per minute than adults (ANOVA: $F_{1,62} = 49.96$, $P < 0.001$) with juveniles consuming less than one mulberry/min (0.4 ± 0.14) and adults consuming nearly three mulberries/min (2.8 ± 0.26; Fig. 2). Juveniles also had a higher rate of failure than adults (ANOVA: $F_{1,62} = 4.11$, $P < 0.047$) with juveniles, on average, having 1.65 (±0.33) failures/min and adults having 1.04 (±0.22) failures/min. Both juveniles and adults seldom dropped a mulberry once it was picked; only 4% of juveniles and 5% of adults had drops (Fisher's exact test, $P = 1.00$). There was no significant difference in the proportion of adults and juveniles which consumed only a piece of a mulberry (Fisher's exact test, $P = 0.52$).

DISCUSSION

Juvenile American Robins were less proficient mulberry foragers than adults; they were less successful at obtaining mulberry fruit and consumed significantly fewer mulberries per minute than adults. Our results strongly indicate that juvenile robins need to develop skills to forage for fruit.

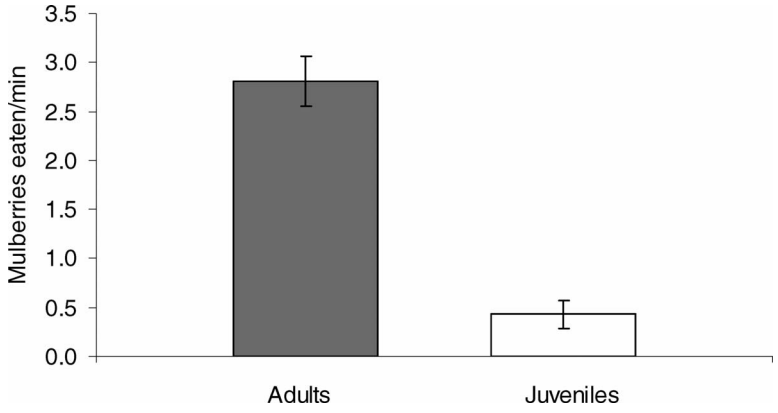

FIG. 2. Juvenile vs. adult American Robins' fruit capture rate per minute.

Other studies have found no differences in foraging rates between juveniles and adults foraging for fruit (Hampe 2001, Bas et al. 2006). One reason for the disparity may be that other researchers observed juveniles that had already developed their skills to forage for fruit. Mulberry, in our study, was the first fruit that juvenile robins learned how to obtain, and the disparity between juveniles and adults may be greatest at this time. If experience is a critical factor in development of foraging skills, juveniles should show improvement when foraging on other fruits later in the season. There is some supporting evidence for this at our field site, where juvenile robins had higher success at obtaining and consuming cherries, which fruit later in the season (Vanderhoff and Eason 2007).

Fruit type may also be an important factor in why some studies found no differences between juveniles and adults. First, fruit type can influence foraging rates; a previous investigation of robins foraging for fruit found that fruit type and, more specifically, size and clustering of fruits within a plant were important in affecting rates of fruit consumption for adults (White and Stiles 1991). Second, type of fruit may also influence the level of skill required to obtain it. Whereas some fruits may be more challenging to acquire and require experience, other fruits may require little or no experience to obtain. For example less experienced Common Whitethroats (*Sylvia communis*) foraged primarily for woody nightshade (*Solanum dulcamara*) berries, a simple fruit, while older birds were able to forage for aggregate blackberries (*Rubus fruticosus*) (Boddy 1991). Similarly, in our study less experienced juveniles had difficulty obtaining mulberry fruit which, like blackberry, is not a simple fruit. Studies that have not found differences between juveniles and adults have focused on simple fruits that may require little or no experience to obtain (glossy buckthorn [*Frangula alnus*], Hampe 2001; Italian buckthorn [*Rhamnus alaternus*], Bas et al. 2006).

Juveniles may be less adept at obtaining fruit than adults due to either physical or cognitive constraints. Gape size is a limiting factor in fruit selection (Wheelwright 1985, Snow and Snow 1988) and juveniles in some species may not have a sufficient gape to obtain certain fruits. However, previous investigations have shown that juvenile gape size does not seem to limit fruit choice or ingestion (White and Stiles 1991, Jung 1992). Cognitive abilities of juveniles may not be fully developed leading to less proficient fruit foraging. For instance, juveniles are often less adept at identifying suitable food items (Whitehead 1984, Caro 1994, Estes et al. 2003). This suggests that juvenile robins may be less able to recognize ripe fruits and, thus, may attempt to pick a higher percentage of unripe fruits. Fruit ripeness can have a two-fold effect on foraging rates; it can result in higher failure rates because fruits cannot be removed or lower consumption rates due to the increased amount of time to remove unripe fruit.

Fruit is a vital resource for birds and it is surprising that relatively few studies have investigated foraging for fruit by juveniles, and the mechanisms involved in their foraging decisions. Our results show that juvenile robins are less proficient at foraging for fruits than adults casting doubt on the assumption that foraging for fruit requires little or no skill acquisition. The assumption that foraging for fruit is easier than other tasks may be accurate; we did not examine this aspect of the development of skills of robins. Future research should be conducted to understand how the rate at which juveniles develop skills at foraging for fruit compares to the rate at which they learn to forage for other food items, as well as the mechanisms that underlie the learning process. Answering these questions will lead to a better understanding of the factors that affect foraging for fruit and add to our knowledge of animal learning, and plant-animal interactions.

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