The Condor 101:272–281

DISTRIBUTION, ABUNDANCE, AND HABITAT CHARACTERISTICS OF THE BUFF-BREASTED FLYCATCHER IN ARIZONA[1]

JOHN A. MARTIN[2] AND MICHAEL L. MORRISON[3]
School of Renewable Natural Resources, University of Arizona, Tucson, AZ 85721, e-mail: lanius@earthlink.net

Abstract. Geographic range and numbers of Buff-breasted Flycatchers (*Empidonax fulvifrons*) have decreased in Arizona in this century. We conducted surveys to locate additional populations, and studied habitat use in relation to availability, and reproductive success. Results suggested that some small populations have disappeared but that others have increased. We estimated reproductive success using an index based on adults' behavior. We found 67 Buff-breasted Flycatcher nests constructed by 44 pairs. Distance to opening was positively correlated with reproductive success rank. We compared used to available areas and nest sites to used areas and found that Buff-breasted Flycatchers inhabited areas dominated by pines, with a sparse oak understory. We found significant associations between Buff-breasted Flycatcher presence and vegetation type, structural stage, canopy cover, and forest patch width. We developed a habitat model to help manage this rare species. We recommend continued monitoring of Buff-breasted Flycatcher populations and creation of open pine forest with an open understory of oak. Fire may facilitate development of potential habitat.

Key words: *Buff-breasted Flycatcher,* Empidonax fulvifrons, *pine forest, reproductive success.*

Resumen. El extensión geográpico y los numeros del Buff-breasted Flycatcher (*Empidonax fulvifrons*) se han dismuniudaran en Arizona. Nosotros conducimos mediciónes agrimensuras a situar poblaciónes adicionales y estudiamos uso de hábitato en relación de desponibilidad y éxito reprodoctivo. Resultas indican que algunas poblaciones pequeños se han desaparecieron, pero otros poblaciónes pequeños se han aumentado. Nosotros estimamamos éxito reprodoctivo usando un índice basado in comportamiento de los adultos. Nosotros encontramos 67 nidos de Buff-breasted Flycatcher, construidos por 44 pares. Distancia a abertura era positivamente correlado con orden de éxito reprodoctivo. Nosotros usamos regreccíon logistico para comparar áreas usadas a áreas obtenibles y nido partido a áreas usadas. Usadas comparadas a obtenibles indican que el Buff-breasted Flycatchers usan areas dominados con pinos con meliza esparacido debajo de robles. Nosostros encontramos asociacíones significativos entre la presencia de Buff-breasted Flycatcher en typo de vegetacion, estructural tablado, alburgue de dosel, y bosque de pedazo ancho. Nosotros desarollamos un modelo del habitato para ayudar a manguar este especie raro. Nosotros recomendamos continuación a estudiar poblaciones del Buff-breasted Flycatcher y creación de abierto bosque de pino con abierto malizo de roble. Fuego puede facilitar desarollo de habitato potencial.

INTRODUCTION

The Buff-breasted Flycatcher (*Empidonax fulvifrons*) is currently a rare, patchily distributed bird in the mountains of southeastern Arizona. It has declined in numbers and geographic range since the 1920s (Phillips et al. 1964), but has apparently never been an abundant bird in Arizona, perhaps because of the Arizona populations' position at the edge of the species' range. There is little published scientific literature concerning the Buff-breasted Flycatcher, and its habitat has not been described quantitatively.

To determine locations and sizes of breeding populations of Buff-breasted Flycatchers in southeastern Arizona mountains, we conducted surveys. To construct a hierarchical habitat model (sensu Johnson 1980), we examined Buff-breasted Flycatcher habitat characteristics on three scales: the forest patch, the used area (second-order selection), and the nest site (third-order selection). We used measurements of vege-

[1] Received 16 February 1998. Accepted 19 January 1999.
[2] Current address: 4849 Lotus St., San Diego, CA 92107.
[3] Current address: Department of Biological Sciences, California State University, Sacramento, CA 95819.

tation structure and floristics, and other habitat variables, to create a multivariate statistical model of Buff-breasted Flycatcher habitat. Simple presence of a species, or even presence in high densities, is not a reliable indicator of habitat of sufficient quality to sustain a population (Van Horne 1983). Therefore, we evaluated reproductive success, and determined the habitat variables most significantly correlated with successful reproduction.

Our specific objectives were to determine: (1) location and size of breeding populations of Buff-breasted Flycatchers, (2) differences between areas used by Buff-breasted Flycatchers and available areas, (3) differences between the areas used by Buff-breasted Flycatchers and their nest sites, (4) whether Buff-breasted Flycatchers are associated with particular coarse-grained vegetation attributes (e.g., structural stage, vegetation type, canopy cover) at a scale approximating the width of forested area in the canyon bottom usually frequented by Buff-breasted Flycatchers (about 100 m), (5) the relationship between Buff-breasted Flycatcher occurrence and the width of the forest patch of potential habitat, and (6) habitat variables associated with successful reproduction.

METHODS

STUDY AREA

We worked in the Chiricahua, Huachuca, Rincon, Santa Catalina, Santa Rita, and Whetstone Mountains of southeastern Arizona. These ranges were primarily north-south oriented, separated by broad flat basins of about 900–1,200 m in elevation. All ranges except the Whetstones rose above 2,590 m in elevation. Areas surveyed for Buff-breasted Flycatchers ranged from 1,550–2,750 m in elevation. Regionally, the climate in southeastern Arizona was semiarid, with bimodal annual precipitation. About half of the 37–63 cm of annual precipitation fell in July and August, with most of the rest falling from mid-November to mid-April. May was the driest month. At Fort Huachuca (elevation 1,420 m), average January temperatures were 7.9°C (average daily maximum and minimum: 14.7 and 1.2°C, respectively), and average July temperatures were 25.3°C (average daily maximum and minimum: 38.4 and 19.1°C, respectively). At higher elevations in the Huachucas, average January and July temperatures were 4.4 and 18.3°C, respectively (Sellers and Hill 1974). Biotic communities were primarily Madrean montane coniferous forest and Madrean evergreen forest and woodland (Brown et al. 1979). Streambeds (containing perennial, seasonal, or intermittent water) were intermittently lined by deciduous trees such as sycamore (*Platanus wrightii*), ash (*Fraxinus velutina*), walnut (*Juglans major*), and willow (*Salix* spp.). Trees in canyon bottoms included chihuahua pine (*Pinus leiophyllus*), apache pine (*P. englemannii*), alligator juniper (*Juniperus deppeanna*), and oak (*Quercus* spp.). Higher on the canyon sides oaks, junipers, and Mexican pinion pines (*P. cembroides*) dominated.

SURVEYS

To determine location and size of breeding populations of Buff-breasted Flycatchers (objective 1), we conducted tape-playback surveys, walking through potential habitat, stopping every 200 m to broadcast Buff-breasted Flycatcher calls (Martin 1997). We selected 23 canyons with records of Buff-breasted Flycatcher occurrence, and 28 canyons randomly selected extending above 1,830 m. We conducted surveys once in each selected canyon, during the months of May and June. Surveys began within 30 min of sunrise and lasted up to about 4 hr.

To assess responsiveness of Buff-breasted Flycatchers to taped calls, we conducted five trials with two observers, one of whom watched a pair of Buff-breasted Flycatchers while the other broadcast a Buff-breasted Flycatcher call 100 m distant. To assess the effectiveness of our surveys, we compared numbers of Buff-breasted Flycatchers detected during surveys with numbers of Buff-breasted Flycatchers we found occupying the survey area over 14–18 subsequent visits (when we monitored reproductive activity). To determine whether a difference in number of birds detected on a survey and number detected in subsequent monitoring was due to a propensity for only one member of a breeding pair to respond to the survey broadcast, we noted the number of broadcast points at which a single Buff-breasted Flycatcher responded to the broadcast, and determined the proportion of these points at which we found breeding pairs during subsequent monitoring efforts.

HABITAT MEASUREMENT

To determine differences between areas used by Buff-breasted Flycatchers and available areas (objective 2), we first determined used areas. A used area was any area that was occupied by a Buff-breasted Flycatcher during the breeding season, regardless of behavior. We were not certain that the area defined as an individual flycatcher's used area represented all of the area used by that individual (i.e., its home range) or the area defended against conspecifics by that individual (i.e., its territory). In 1995 we determined used areas by observing individual flycatchers for 30 min and constructing minimum convex polygons (Mohr 1947) of locations recorded at 3-min intervals. We centered vegetation sampling plots on these polygons, and at two points (peripheral plots) on opposite sides of the used area, 30 m from the center. In 1996 we recorded one to four locations for each Buff-breasted Flycatcher in conjunction with 14–18 subsequent visits to monitor reproductive activity (approximately every 5 days). Six weeks after the median start date of initiation of first nesting attempts of the season, we constructed minimum convex polygons from the sets of locations. We placed 3 vegetation sampling plots in each used-area polygon.

Using a method based on Noon (1981), we sampled vegetation and other habitat variables. We sampled within a circle of 15-m radius. Trees in the circle were counted, by species and diameter at breast height (dbh) class (10–20, 21–30, 31–40, 41–50, 51–60, and >60 cm). We estimated height (m) and vigor (on an ascending scale of 1–5, based on amount of live foliage compared to height and dbh), and measured dbh, of the tallest specimen of each tree species in the circle. We counted the number of shrub species in the circle. We recorded vegetative cover intersecting 29 vertical point-intercept lines, in 6 (1995) or 5 (1996) height categories. Slope, slope position, aspect, distance to riparian zone, and distance to opening (area > 0.04 ha without vegetation exceeding 10 m in height) were recorded. We estimated Universal Transverse Mercator coordinates of each used area using USGS 7.5′ topographic maps.

We conducted the same sampling procedure at 30–36 systematically placed plots within each canyon in areas available to Buff-breasted Flycatchers. Availability plots were placed within one mean + SD of the distance of nests from the riparian zone.

To determine differences between used areas and nest sites (objective 3), we recorded all of the habitat measurements stated above for used vs. available areas at vegetation sampling plots centered on the nest sites. In addition, we recorded nest tree species, nest tree height, nest height, nest tree dbh, compass direction of nest from trunk, distance of nest from trunk, distance from the rim of the nest to vegetation above, distance of nest from outer edge of vegetation of the nest tree, and diameter of the supporting branch.

To address objectives 4 and 5, we re-visited 24 canyons (10 in the Huachucas and 14 in the Chiricahuas) in August 1996 that we had previously surveyed for Buff-breasted Flycatchers, and recorded vegetation type after Brown et al. (1979), structural stage, and estimated canopy coverage after Reynolds et al. (1992) of any forest vegetation type within a 100-m radius of 514 points (approximating locations of survey broadcast points) and also estimated width of the forest patch.

REPRODUCTIVE SUCCESS

We monitored reproductive success of Buff-breasted Flycatchers in 8 canyons in the Huachuca and Chiricahua mountains. Every 4–8 days, we observed Buff-breasted Flycatchers at each established used area for 30 min and noted the following behaviors: presence, singing, pairing, carrying of nest material, nest construction, incubation, carrying of food, carrying of fecal sacs, and presence of at least one fledgling. To quantify breeding success while minimizing disturbance to the birds, we calculated an index of reproductive activity (Vickery et al. 1992). Birds were assigned a rank corresponding with a degree of reproductive success, based on easily observable behaviors. Ranks were as follows: 1 = occupation of a territory for at least 8 weeks, 2 = pair formation, 3 = nest building, egg laying, or incubation, 4 = presence of nestlings, 5 = fledging, 6 = evidence of a second nesting attempt, after successful fledging in the first attempt, and 7 = evidence of fledging success in first and second nesting attempts.

Ten nests were sufficiently low and free of overhanging vegetation to check the contents for evidence of cowbird parasitism. Using a mirror pole 4.7 m long, we checked the contents of each of these 10 accessible nests once during the incubation or nestling periods.

DATA ANALYSES

We used logistic regression (LR) to compare used areas to available areas and to nest sites (objectives 2 and 3). We first eliminated variables that occurred in $< 10\%$ of the sampling plots, variables that did not show significant between-group differences univariately (Mann-Whitney U-test), and the less significant variable of pairs of correlated variables ($R > 0.8$). We performed separate LR analyses for each of the eight canyons and each of the two mountain ranges in which we measured Buff-breasted Flycatcher habitat, and for both mountain ranges combined, then used variables selected in these models to make a more broadly applicable overall model. We repeated this selection and LR procedure with the 12 nest site vs. used area models, the successful nest site vs. unsuccessful nest site model, and the successful used area vs. unsuccessful used area model. Because birds are thought to select habitat hierarchically, on different "orders" (Johnson 1980), we performed separate analyses to compare used to available areas, and used areas to nest sites.

Despite between-year differences in the technique employed to determine used areas, we lumped data from 1995 and 1996 to construct the overall used vs. available LR model. MANOVA analysis using the same variables that were input to create the overall used vs. available model showed significant multivariate differences in habitat variables between mountain ranges, but significant univariate differences were few. Because the 1995 technique was used only in the Huachuca Mountains and the 1996 technique was used only in the Chiricahua Mountains, we could not separate the effect of the techniques from the effect of geographical area.

We examined the validity of the overall used vs. available model by randomly sampling approximately 75% of the plots and running the LR procedure an additional 10 times, recording the mean and standard deviation of correct classification rate of used areas, and the number of times each variable was selected. This validation procedure also was performed for the overall nest site vs. used area model.

To address objectives 3 and 4, we tested vegetation type, forest structural stage, canopy cover category, forest width, and these four variables combined, for association with Buff-breasted Flycatcher presence at survey broadcast points using χ^2 contingency tables. Because sample sizes in some vegetation types were small, we combined vegetation types into 3 categories: Madrean pine forest, Madrean oak woodland, and all other forest types. We also combined forest patch widths into two categories ($\leq$149 m and $\geq$150 m), and structural stage into two categories (young forest: trees < 31 cm dbh, and mid-aged to old forest: trees > 31 cm dbh). We tested for these associations twice: once including all vegetation types recorded, and once including only vegetation types that included pines (Madrean pine forest, Madrean pine-oak forest, Madrean pine-juniper forest, and Madrean oak-pine woodland).

To identify habitat characteristics associated with successful reproduction (objective 6), we performed LR analyses comparing successful (fledging ≥ 1 young) to unsuccessful nests, and successful to unsuccessful used areas. We performed multiple regressions, with stepwise variable entry (P-to-enter ≤ 0.05, P-to-remove ≥ 0.1) of reproductive success rank on habitat variables of used areas, employing the same criteria to select regressors that we used in the initial canyon-specific LR procedures.

RESULTS

BROADCAST SURVEYS

Buff-breasted Flycatchers found in 1995–1996. We counted 86 Buff-breasted Flycatchers in 37.9 km^2 surveyed. While conducting behavioral observations, we found 35 more Buff-breasted Flycatchers, bringing the total number of adults detected in the course of the study to 121. For locations see Martin (1997).

Evaluation of survey technique. Flycatchers responded to the broadcast in four out of five trials. However, the birds that did not respond had responded to the previous broadcast about 5 min earlier, at which time they moved to the area from which the broadcast was made. The subsequent broadcast was 100 m from this point.

In canyons in which we subsequently monitored nesting activity, we found 58 adult Buff-breasted Flycatchers during surveys and 80 adults over the entire monitoring period (14–18 visits distributed over the 3-month breeding season). At 12 (80%) of the 15 survey points where single Buff-breasted Flycatchers had responded to the initial broadcast, we subsequently found breeding pairs.

TABLE 1. Habitat characteristics (mean ± SD) distinguishing areas used by Buff-breasted Flycatchers from available areas.

Habitat variable	Used	Available
Slope (°)	11.3 ± 8.6[a]	17.8 ± 10.5
% cover apache and chihuahua pine, >10 m	22 ± 20	9 ± 14
% cover oak, 5–10 m	9 ± 12	15 ± 16
No. oak trees, 10–20 cm dbh	5.9 ± 7.5	11.4 ± 12.3
Probability shrub yucca present	0.13 ± 0.34	0.35 ± 0.48
No. apache and chihuahua pines, 40–50 cm dbh	1.5 ± 2.3	0.55 ± 0.91

[a] Used and available compared, Mann-Whitney *U*-test, all *P*s < 0.001.

REPRODUCTIVE SUCCESS

Used areas. We ranked the reproductive success of Buff-breasted Flycatchers in 56 used areas (37 in 1995 and 19 in 1996). Six areas received a rank of 0, 5 received a rank of 1, none received a rank of 2, 13 received a rank of 3, 7 received a rank of 4, 22 received a rank of 5, 1 received a rank of 6, and 2 received a rank of 7. Of the 27 areas that received a rank ≥ 3 (indicating presence of a breeding pair) in 1995, 13 (48%) received a rank ≥ 5 (indicating successful fledging). Of the 19 areas that received a rank ≥ 3 in 1996, 12 (63%) successfully fledged young.

Nests. We found 67 Buff-breasted Flycatcher nests, constructed by 44 pairs. Twenty-seven (40%) successfully fledged young, 37 (55%) failed, and the outcomes of 3 were unknown. Median fledging date was between 1 July and 6 July in 1995, and 9 July and 14 July in 1996. Twenty-three of the nests were subsequent attempts following failure of the preceding nest, and 3 were second attempts after a successful first brood. At 20 of the 36 failed nests, we found evidence of probable Steller's Jay (*Cyanocitta stelleri*) or Mexican Jay (*Aphelocoma ultramarina*) predation (usually the remains of the nest on the ground). Two nests were probably destroyed by severe weather. One nest was destroyed when the nest tree was cut during campground maintenance-related tree cutting. We have no evidence for cause of failure of the remaining 13 failed nests, but cannot rule out predation. We found no cowbird eggs or nestlings in the 10 nests we checked, and no cowbird fledglings among the 21 broods of Buff-breasted Flycatcher fledglings from unchecked nests.

HABITAT CHARACTERISTICS

Coarse-grained variable analyses. At 574 survey broadcast points, in 26 canyons, 12 different vegetation types were recorded (Martin 1997). We recorded forest patch widths ranging from 50 m to 2,000 m. We found Buff-breasted Flycatchers significantly more frequently in Madrean pine forest than in Madrean oak woodland or other forest types (observed = 49, expected = 27, $P < 0.001$). Buff-breasted Flycatchers were found significantly more frequently in forest patches > 150 m wide (observed = 40, expected = 28.7, $P = 0.004$), in forests with moderately open canopy cover (observed = 49, expected = 26.1, $P < 0.001$), and in mid-aged to old forest structural stages (observed = 55, expected = 43.8, $P = 0.001$). When we restricted our analysis to vegetation types with a pine component (Madrean pine-oak forest, Madrean pine forest, Madrean pine-juniper forest, and Madrean oak-pine woodland), we found Buff-breasted Flycatchers significantly more frequently in Madrean pine-oak forest (observed = 49, expected = 42.8, P = 0.043). In pine forests, there was no significant association between Buff-breasted Flycatcher occurrence and structural stage, but Buff-breasted Flycatchers were encountered significantly more frequently in forest patches > 150 m wide than in narrower patches (observed = 37, expected = 18.2, $P < 0.001$), and significantly more frequently under moderately open canopy cover (observed = 49, expected = 34.1, $P < 0.001$). Buff-breasted Flycatcher numbers were not significantly different from expected by mountain range.

Used vs. available. The LR procedure selected six variables differentiating between used and available areas (Table 1). The model correctly classified 60.3% of the used area plots, 84.2% of the available plots, and 74.9% of all plots. Used areas had greater pine cover, less slope, higher probability of presence of yucca, fewer oak trees 10–20 cm dbh, and less cover of oak 5–10 m. All these differences were highly significant ($P < 0.01$). When we examined the va-

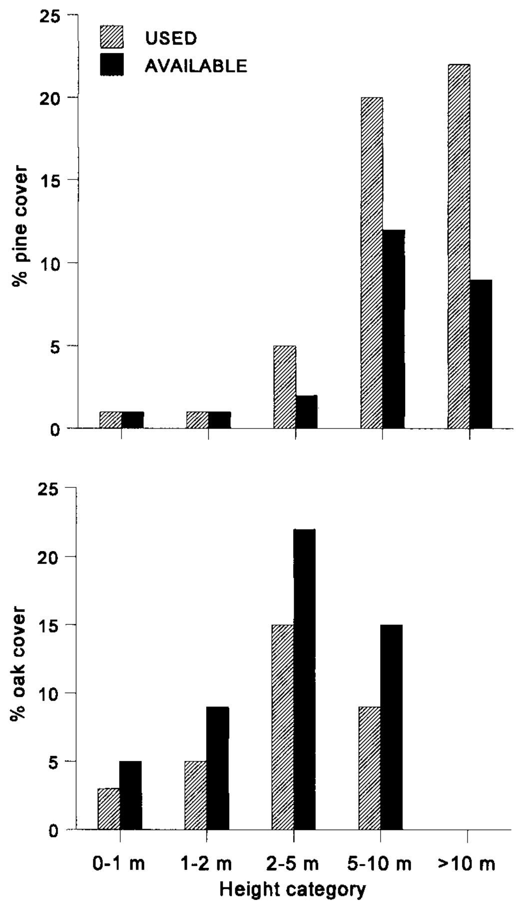

FIGURE 1. Percent pine and oak cover in areas used by Buff-breasted Flycatchers and available areas, Huachuca and Chiricahua Mountains combined, 1995–1996.

lidity of the overall used vs. available model, the average correct classification rate of used areas was 59.56 ± 4.9%. Apache or chihuahua pine cover in used areas was highly significantly greater than in available areas in all height categories above 2 m (all $P < 0.001$), significantly greater than in available from 1–2 m (P = 0.029), but did not differ significantly from available at 0–1 m. Oak cover was significantly less in used areas than available areas in all height categories (all $P < 0.003$) (Fig. 1).

Nest sites vs. used areas. The LR procedure selected three variables, constructing a model that correctly classified 30.0% of nest sites, 91.0% of used areas, and 72.6% of all sampling plots (Table 2). Nest sites had greater chihuahua and apache pine cover >10 m, more apache and chihuahua pines 10–20 cm dbh, and fewer shrub species than did used areas (all $P < 0.05$). When we examined the validity of the overall nest site vs. used area model, the average correct classification rate of nest sites was 13.1 ± 9.5%.

Habitat characteristics associated with successful reproduction. Successful used areas were more likely to include chihuahua pine as a shrub than were unsuccessful used areas. The model correctly classified 72.2% of successful used areas, 60.6% of unsuccessful used areas, and 72.6% of all sampling plots.

Successful nest sites differed from unsuccessful nest sites in having more live vegetation 0–1 m, less silverleaf oak (*Quercus hypoleucoides*) cover 1–2 m, and more species of shrubs (all $P < 0.05$). The model correctly classified 51.8% of successful nest sites, 85.0% of unsuccessful nest sites, and 71.6% of all the sampling plots (Table 3). Most of the difference in live vegetative cover 0–1 m tall was due to a difference in grass cover.

The stepwise multiple regression analysis examining the relationship between habitat variables and reproductive-success ranks showed that habitat supporting successful reproduction in Buff-breasted Flycatchers is characterized by greater distance to an opening, presence of manzanita (*Arctostaphylos pungens*) and douglas-fir (*Pseudotsuga menziesii*) as shrubs, fewer shrub-sized apache pines, more young pine trees, decreased Arizona white oak (*Quercus arizonica*) vigor, and proximity to the bottom of the slope. The following equation explained 38% of the

TABLE 2. Habitat characteristics (mean ± SD) distinguishing areas used by Buff-breasted Flycatchers from nest sites.

Habitat variable	Used	Nest sites
No. apache and chihuahua pines, 10–20 cm dbh	3.1 ± 3.6[a]	4.5 ± 4.8
% cover apache and chihuahua pine, > 10 m	22 ± 20	34 ± 19
No. of shrub species	7.9 ± 3.3	6.4 ± 3.1

[a] Used and available compared, Mann-Whitney U-test, all $Ps < 0.05$.

TABLE 3. Habitat characteristics (mean ± SD) distinguishing successful from unsuccessful Buff-breasted Flycatcher nest sites.

Habitat variable	Successful	Unsuccessful
% cover silverleaf oak, 1–2 m	0.51 ± 1.25[a]	3 ± 5
% total live cover, 0–1 m	41 ± 19	30 ± 16
No. of shrub species	7.8 ± 3.3	5.4 ± 2.6

[a] Used and available compared, Mann-Whitney *U*-test, all $Ps < 0.05$.

variation in reproductive success rank (adjusted $R^2 = 0.376$): Buff-breasted Flycatcher reproductive success rank = 4.54 + 0.006(distance to opening) − 0.327(vigor of tallest Arizona white oak) + 2.70(% cover douglas-fir, 1–2 m) + 0.972(probability of presence of manzanita) + 1.10(probability of presence of douglas-fir as a shrub) − 1.98(slope position) − 1.01(probability of presence of apache pine as a shrub) + 0.85(number of apache and chihuahua pines 10–20 cm dbh).

DISCUSSION

ABUNDANCE AND DISTRIBUTION

We found some evidence that even within the last 15 years, some small populations (isolated groups of 1–2 breeding pairs) of Buff-breasted Flycatchers have disappeared from the mountain ranges we surveyed. Either these small populations have indeed disappeared, or our broadcast survey technique was not effective. A comparison of the numbers of Buff-breasted Flycatchers detected on surveys with the number found in subsequent monitoring suggests that broadcast surveys detect nearly 30% fewer birds than are present in the surveyed area, but records suggest that surveys more accurately assess the number of breeding pairs in the area. On many occasions, only one Buff-breasted Flycatcher responded to a survey broadcast, but in subsequent monitoring we found the area to be occupied by a breeding pair. The female of the pair may not have responded because she did not wish to draw attention to the nest. Our trials with two observers (one of whom watched a pair or individual bird while the other played a tape of the call 100 m away) suggested that the birds usually responded to a broadcast < 100 m away, but were reluctant to leave their territory to respond to a more distant broadcast. Buff-breasted Flycatchers seemed quite responsive to broadcasts of taped calls.

Although there is evidence that some small populations have disappeared in the last 15 years, where they still occur, Buff-breasted Flycatchers are more abundant than they were 15 years ago. In six out of the seven canyons in which we and Bowers and Dunning (1994) found the species, we found more birds than they did. The most substantial increases were in Carr Canyon (from 9 birds to 17), Sawmill Canyon (from 11 to 20), Rucker Canyon (from 1 to 8), and West Turkey Creek Canyon (from 5 to 14). However, these differences may reflect inter-observer variability rather than actual differences in Buff-breasted Flycatcher abundance.

These conflicting lines of evidence of Buff-breasted Flycatcher population trends, and the paucity of specific survey data, point out the need for continued monitoring of this species. Wilcove and Terborgh (1984) hypothesized that populations at the edge of a species' range (like those of Buff-breasted Flycatchers in Arizona) should be the first to decrease when overall numbers of the species fall. These small populations of breeding Buff-breasted Flycatchers may persist over the long term due to a "rescue effect" (i.e., disappear temporarily, to be re-established in subsequent years by colonists from other popultions) (Brown and Kodric-Brown 1977). Our short-term study and that of Bowers and Dunning (1994) are insufficient to draw conclusions regarding long-term population trends of Buff-breasted Flycatchers in Arizona. Longer-term surveys are needed to determine whether the decline in Arizona Buff-breasted Flycatcher numbers that began in the early 20th century continues.

We re-affirmed that the Buff-breasted Flycatcher is discontinuous and patchy in distribution. Swarth (1914), Marshall (1957), and Russell and Monson (in press; pers. comm.) have all noted the spotty and unpredictable distribution of the Buff-breasted Flycatcher. Dates and locations of their observations suggest that this distributional pattern is not a recent phenomenon, nor restricted to Arizona.

HABITAT CHARACTERISTICS

The most important variable (indicated by highest partial correlation coefficient) differentiating used from available areas was percent cover of chihuahua and apache pine >10 m (although pine cover in all height categories above 2 m was greater in used areas than available areas; Fig. 1). Many observers (Marshall 1957, Phillips et al. 1964, Bowers and Dunning 1994) have noted the Buff-breasted Flycatcher's preference for open-canopy pine forest. Where we found Buff-breasted Flycatchers, apache or chihuahua pines were always present. They used the trees as foraging and song perches, foraging substrates, and nest substrates. Eighty-nine percent of nests we found were in these tree species. Presence of either or both of these tree species may be a proximate factor in habitat selection by Buff-breasted Flycatchers.

Slope was another important component of the model. Used areas were usually clustered in the bottom of a canyon. Buff-breasted Flycatchers tend to inhabit flatter areas, on the canyon bottom, although they were found nesting successfully in areas with slopes as steep as 35°.

Two of the variables chosen reflected negative associations with oak. Although five oak species were abundant in mountain ranges and canyons inhabited by Buff-breasted Flycatchers, and some oak was found in nearly every sampling plot, there was less oak cover between 5–10 m, and fewer oak trees 10–20 cm dbh in used areas than available. On average, there were just over half as many of these small oak trees in used areas as in available areas. In all height categories, oak cover was greater in available areas than used areas (Fig. 1). On 6.5% of the used area sampling plots, no oak trees were detected. We have no quantitative data on use of oaks by Buff-breasted Flycatchers, but we saw them use oaks frequently as song and foraging perches, and as foraging substrates. Although Buff-breasted Flycatchers are known to use Arizona white oak as a nest substrate (Bowers and Dunning 1994), none of the 67 nests we found were in oaks.

The low rate of correct classification for our model differentiating nest sites from used areas suggests that at the scale we measured, differences between nest sites and used areas were not biologically significant. Correct nest-site classification rates were consistently poor in the 10 trials of our validation procedure, and only one variable (% cover apache or chihuahua pine > 10 m) was consistently selected as distinguishing between nest sites and used areas.

The most important finding of our analysis of coarse-grained variables at survey broadcast points was that Buff-breasted Flycatchers prefer wider areas of pine forest. When we restricted our analysis to vegetation types with a pine component, we found that Buff-breasted Flycatchers occurred more frequently than expected in forest patches > 150 m wide.

Characteristics associated with successful reproduction. When we compared successful and unsuccessful nest sites, the low correct classification rate for successful nest sites, and consistently poor correct classification rates in validation trials, suggested that at the scale we measured, differences in habitat variables between successful and unsuccessful nests were not biologically significant. The single variable selected in the model comparing successful used areas to unsuccessful used areas was presence of chihuahua pine as a shrub. However, presence of chihuahua pine as a shrub was correlated with total pine cover (r = 0.41). Greater total pine cover probably reduces search effectiveness of nest predators by increasing the number of possible nest substrates to examine, and by reducing visibility in the canopy.

Our multiple regression model regressing habitat variables on reproductive success rank selected eight variables and did not include presence of chihuahua pine as a shrub (i.e., no variables were shared between this model and the successful used area vs. unsuccessful used area LR model). Distance to opening had the highest correlation coefficient of the variables selected (r = 0.33). Proximity to an edge is correlated with increased nest predation rates in some passerine birds (Gates and Gysel 1978). The positive correlation between reproductive success rank in Buff-breasted Flycatchers and distance to opening may be due to increased nest predation rates at the edge of the patch of pine forest.

FACTORS POSSIBLY LIMITING ABUNDANCE AND DISTRIBUTION

Brood parasitism. Although Brown-headed Cowbirds (*Molothrus ater*) and Bronzed Cowbirds (*M. aeneus*) were common in the canyons occupied by Buff-breasted Flycatchers, parasitized other passerine species there (Christoferson 1996), and are known to parasitize Buff-breasted Flycatchers (Bowers and Dunning 1984), we found no evidence of cowbird parasitism on Buff-breasted Flycatchers.

Predation. Martin (1992) noted that nest predation was the primary source of nestling mortality in most North American passerines for which nesting success has been studied, and is thus perhaps their most important decimating factor. Buff-breasted Flycatcher nests are known to have been depredated by Mexican Jays (Bowers 1983, unpubl. data) and Steller's Jays (Martin 1997). At 20 of the 36 failed nests observed, we found evidence of probable jay predation. At Carr Canyon in 1995, the 100% nest failure rate (n = 15) may have been attributable to an artificially elevated jay population due to supplementary feeding at two popular campgrounds on opposite ends of the area inhabited by the Buff-breasted Flycatchers.

Changes in vegetation structure and floristics. Phillips et al. (1964, 1968) suggested that fire suppression may have reduced the amount of potential habitat available to Buff-breasted Flycatchers. Livestock grazing and fire suppression in the birds' former and current range have allowed shrubs to proliferate, reducing the openness of pine forests, and thus their suitability to Buff-breasted Flycatchers. It is widely accepted that fire suppression has reduced the openness of southwestern pine forests (Cooper 1960, Covington and Moore 1994). Prescribed burning may improve suitability of an area as potential Buff-breasted Flycatcher habitat by reducing the oak understory. Horton (1987) investigated the effect of prescribed burning in pine-oak forest in the Santa Catalina Mountains, an area potentially habitable by Buff-breasted Flycatchers. He found that prescribed burning reduced the number of oak trees < 15 cm dbh by approximately 50%. We found the number of oak trees 10–20 cm dbh in Buff-breasted Flycatcher used areas to be about 50% of that in available areas.

Grazing by domestic livestock, in combination with fire suppression in open ponderosa pine (*Pinus ponderosa*) forests with a lush herbaceous understory of perennial grasses, is known to change the vegetation structure of the forest (Bock et al. 1992). Rummell (1961) and Madanay and West (1983) found greater tree densities and less herbaceous ground cover in grazed ponderosa pine forests than in ungrazed forests, and concluded that livestock grazing was the primary agent in the process of reducing herbaceous cover and encouraging the proliferation of woody species. This shift in vegetation structure concurrently reduced flammability and was facilitated by decreased fire frequency.

These grazing and fire suppression-induced changes to vegetation structure and floristics in Arizona pine-oak forests may not be entirely responsible for the Buff-breasted Flycatcher's rarity. Our observations suggest that apparently suitable habitat in our study area is unoccupied. S. M. Russell (pers. comm.) noted that in the pine-oak forests of Sonora, Mexico, where lack of fire suppression creates a very open understory, Buff-breasted Flycatchers are uncommon and local. Future investigators should compare pine forests in areas formerly occupied by Buff-breasted Flycatchers (i.e., the White Mountains of Arizona) with our model to determine whether reduction in habitat quality or availability is responsible for the species' range contraction.

ACKNOWLEDGMENTS

This research was funded by the Arizona Game and Fish Department Heritage Fund, grants no. I94004 and I96007. We thank Sheridan Stone and Steve Schacht for logistical assistance, Helen and Noel Snyder for accommodations, Linnea Hall, Amy Antonioli, Hillary Heard, Trish Cutler, Dave Griffin, Chris Kirkpatrick, Scott McCarthy, Justin White, and Suellen Lynn for field assistance. We thank R. W. Mannan and G. R. Ruyle for reviewing earlier drafts of this manuscript.

LITERATURE CITED

Bock, C. E., V. A. Saab, T. D. Rich, and D. S. Dobkin. 1992. Effects of livestock grazing on Neotropical migratory landbirds in western North America, p. 296–309. *In* D. M. Finch and P. W. Stengel [eds.], Status and management of Neotropical migratory birds. Gen. Tech. Rept. RM-299. US Dept. Agriculture, For. Serv., Rocky Mountain Forest and Range Exp. Sta., Fort Collins, CO

Bowers, R. K., Jr., and J. B. Dunning. 1984. Nest parasitism by cowbirds on Buff-breasted Flycatchers, with comments on nest site selection. Wilson Bull. 96:718–719

Bowers, R. K., Jr., and J. B. Dunning. 1994. Buff-breasted Flycatcher (*Empidonax fulvifrons*). *In* A. Poole and F. Gill [eds.], The birds of North America, No. 125. The Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, DC.

Brown, D. E., C. H. Lowe, and C. P. Pase. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the southwest. J. Arizona-Nevada Acad. Sci. 14(Suppl. III):1–16.

BROWN, J. H., AND A. KODRIC-BROWN. 1977. Turnover rates in insular biogeography: effects of immigration on extinction. Ecology 58:445–449.

CHRISTOFERSON, L. L. 1996. Defining breeding habitat for Painted Redstarts, Solitary Vireos, and Western Wood-pewees in riparian area of southeastern Arizona. M.Sc. thesis, Univ. Arizona, Tucson, AZ.

COOPER, C. F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. Ecol. Monogr. 30:129–164.

COVINGTON, W. W., AND M. M. MOORE. 1994. Southwestern ponderosa pine forest structure and resource conditions: changes since Euro-American settlement. J. Forestry 92:39–47.

GATES, J. E., AND L. W. GYSEL. 1978. Avian nest dispersion and fledgling success in field-forest ecotones. Ecology 59:871–883.

HORTON, S. P. 1987. Effects of prescribed burning on breeding birds in a ponderosa pine forest. M.Sc. thesis, Univ. Arizona, Tucson, AZ.

JOHNSON, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

MADANAY, M., AND N. WEST. 1983. Livestock grazing—fire regime interactions in montane forests of Zion National Park, Utah. Ecology 64:661–667.

MARSHALL, J. T. 1957. Birds of pine-oak woodland in southern Arizona and adjacent Mexico. Pacific Coast Avifauna 32:1–125.

MARTIN, J. A. 1997. Distribution, abundance and habitat characteristics of the Buff-breasted Flycatcher in Arizona. M.Sc. thesis, Univ. Arizona, Tucson, AZ.

MARTIN, T. E. 1992. Breeding productivity considerations: What are the appropriate habitat features for management?, p. 455–473. *In* J. M. Hagan III and D. W. Johnston [eds.], Ecology and conservation of Neotropical migrant landbirds. Smithson. Inst. Press, Washington, DC.

MOHR, C. O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37:223–249.

NOON, B. R. 1981. Techniques for sampling avian habitats, p. 42–51. *In* D. E. Capen [ed.], The use of multivariate statistics in the study of wildlife habitat. US For. Serv. Gen. Tech. Rep. RM-87. Rocky Mountain Forest and Range Exp. Station, Fort Collins, CO.

PHILLIPS, A. R. 1968. The instability of the distribution of land birds in the southwest. Pap. Arch. Soc. New Mex. 1:129–162.

PHILLIPS, A. R., J. MARSHALL, AND G. MONSON. 1964. The birds of Arizona. Univ. Arizona Press, Tucson, AZ.

REYNOLDS, R. T., R. T. GRAHAM, M. H. REISER, R. L. BASSETT, P. L. KENNEDY, D. A. BOYCE JR., G. GOODWIN, R. SMITH, AND E. L. FISHER. 1992. Management recommendations for the Northern Goshawk in the Southwestern United States. USDA Forest Service Gen. Tech. Rept. RM-217. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, CO.

RUMMELL, R. S. 1951. Some effects of livestock grazing on ponderosa pine forest and range in central Washington. Ecology 32:594–607.

RUSSELL, S. M., AND G. MONSON. In press. The birds of Sonora. Univ. Arizona Press, Tucson, AZ.

SELLERS, W. D., AND R. H. HILL. 1974. Arizona climate. Univ. Arizona Press, Tucson, AZ.

SWARTH, H. S. 1914. A distributional list of the birds of Arizona. Pacific Coast Avifauna 10:1–133.

VAN HORNE, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47:893–901.

VICKERY, P. D., M. L. HUNTER, AND J. V. WELLS. 1992. Use of a new reproductive index to evaluate relationship between habitat quality and breeding success. Auk 109:697–705

WILCOVE, D. S., AND J. W. TERBORGH. 1984. Patterns of population decline in birds. Am. Birds 38:10–13.