ARIZONA COOPERATIVE FISH AND WILDLIFE RESEARCH UNIT - JUNE 2005

Reproductive success and habitat associations of riparian birds within the Sky Island mountains of southeastern Arizona

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Wildlife Research Report #2005-07

Funding provided by:

T & E, Inc.

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Final Report

Submitted to:

Arizona Bird Conservation Initiative
Arizona Game and Fish Department

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1 June 2005

Suggested Citation: Kirkpatrick, C., and C. J. Conway. 2005. Reproductive success and habitat associations of riparian birds within the Sky Island mountains of southeastern Arizona. Final Report submitted to Arizona Bird Conservation Initiative, Arizona Game and Fish Department. Wildlife Research Report #2005-07. U. S. Geological Survey Arizona Cooperative Fish and Wildlife Research Unit, Tucson, Arizona.

INTRODUCTION

Montane forests in the Santa Catalina Mountains of southeastern Arizona support a unique and diverse avian community, including 11 priority species identified by Partners in Flight (PIF) as needing conservation efforts in Arizona (Latta et al. 1999). This avian community is vulnerable to disturbance because the area encompassed by montane forests represents only a small fraction of the total landmass of the region. Moreover, the highest densities of breeding birds in the Santa Catalina Mountains are concentrated in a relatively small number of drainages that contain montane riparian vegetation (C. Kirkpatrick, personal observation). In recent years, the potential for disturbance to these important breeding areas has increased dramatically. For example, the frequency of large wildfires has increased in southeastern Arizona (Swetnam et al. 1999) and much of the high-elevation forest in the Santa Catalina Mountains was burned (much of it severely) during consecutive wildfires in 2002 and 2003. In addition, nest predation is known to be a leading cause of reproductive failure in songbirds (Ricklefs 1969) and data from the Santa Catalina Mountains (Kirkpatrick et al. 2004) suggest that birds such as Red-faced Warblers and Cordilleran Flycatchers (two of the 11 PIF Priority Species) are suffering from high rates of nest failure in southeastern Arizona compared to other areas in the State (Martin and Barber 1995, Lowther 2000). Most of these nest failures are due to nest predators (Kirkpatrick et al. 2004); however, we have yet to identify the species of predators responsible for these nest depredations.

In light of these potential threats, we need additional information about montane forest birds to better manage and conserve this unique avian community. Studies have been conducted to determine the distribution and abundance of montane forest birds in Southeastern Arizona (e.g., Marshall 1957, Conway and Kirkpatrick 2001); however, relatively few studies have examined the basic breeding biology (clutch size, number of nesting attempts, etc.) or measured reproductive success for populations of these species. Moreover, few studies have attempted to correlate reproductive success with variation in habitat quality or identify common nest predators. To address these issues, we have initiated a long-term study of breeding birds in the Santa Catalina Mountains of southeastern Arizona. Results from this study will provide managers with important information to better manage many species of birds in the Santa Catalina Mountains and elsewhere in the Sky Island Mountains of southeastern Arizona. More specifically, results will provide managers with data to better conserve populations of the 11 Arizona PIF priority species (Latta et al. 1999). These species are Broad-tailed Hummingbird, Cordilleran Flycatcher, Pygmy Nuthatch, Hermit Thrush, Plumbeous Vireo, Virginia's Warbler (*Vermivora virginiae*), Orange-crowned Warbler, Grace's Warbler (*Dendroica graciae*), Red-faced Warbler (*Cardellina rubrofrons*), Olive Warbler, and Western Tanager (see Table 1 for additional scientific names). This report summarizes results from the first 3 years (2002-2004) of the study.

OBJECTIVES

1) Measure reproductive success, and collect basic information on the breeding biology of montane riparian bird species by locating and monitoring nests.
2) Quantify habitat characteristics associated with successful and unsuccessful nests by sampling vegetation features at nest sites.
3) Identify common nest predators through the use of time-lapse video cameras placed at nests.

METHODS

Study area - We conducted this study in high-elevation mixed-conifer and montane riparian forests (2,300 to 2,800 m elevation) of the Santa Catalina Mountains, Pima County, Arizona. We located five potential study plots ranging from 16 to 20 ha in size (Lower Bear Wallow, Marshall Gulch, Lemmon Park, Upper Bear Wallow, and Upper Sabino Canyon; Fig. 1). All of the plots (except Lemmon Park) were located in drainages and contained extensive areas of montane riparian forest vegetation.

Reproductive success and causes of nest failures - From 2002 to 2004, we searched for nests of montane forest bird species in each of the nest search plots beginning in late April. In general, a sample size of >20 nests per species is required for an adequate estimate of reproductive success (Hensler and Nichols 1981). Therefore, we concentrated our efforts on locating as many nests as possible during the breeding season. Because most montane forest bird species build nests and feed young throughout the day, we searched for nests from sunrise until mid-afternoon to maximize our sample size of nests.

Once we located a nest, we marked its location using a hand-held Global Positioning System (GPS) unit and placed a small piece of flagging >5 m from the nest site. We monitored the nest by revisiting the nest site every three to four days to check the status of the nest, document critical dates (e.g., nest initiation [date first egg laid], hatching, fledging), and attempt to determine the fate of the nest (e.g., successful, abandoned, depredated, unknown). We followed standardized nest searching and monitoring protocols to reduce the disturbance to adults and young at nests (Martin and Geupel 1993). We could not determine the fates of some nests nor could we conduct vegetation sampling at other nests because of interruptions to our fieldwork due to two major wildfires that burned in the Santa Catalina Mountains (Bullock wildfire - June 2002; Aspen wildfire - June/July 2003).

Habitat characteristics at nests - Following the completion of each nest attempt, we measured habitat characteristics associated with each nest using standardized vegetation sampling protocols derived from the BBIRD nest monitoring program (Martin et al. 1997). These protocols describe techniques for sampling vegetation and topographic features at nests. We divided the vegetation sampling at nests into two parts: 1) information on the nest itself (nest height, nest tree species or substrate, percentage of nest exposed to view, etc.) and 2) information on the vegetation/topographic features in the immediate vicinity of the nest (slope, canopy cover, number of shrub/sapling stems [measured at 10 cm height] in a 5-m radius plot centered on the nest).

Identification of common nest predators - During the spring of 2005, we used four time-lapse video cameras (Fuhrman Diversified, Seabrook Texas) to monitor nests of ground-nesting birds within our five study plots. We placed cameras at nests of Yellow-eyed Juncos and Red-faced Warblers primarily because these two species were the most common ground-nesting birds within our study area. To limit the disturbance that the cameras might cause, we camouflaged the equipment using paint and fabric and placed the camera heads approximately 30-50 cm from nests (closer than 30 cm appeared to disturb some birds). We ran a 20 m cable from the camera back to a concealed location where the video recorder and battery were located. Each day we

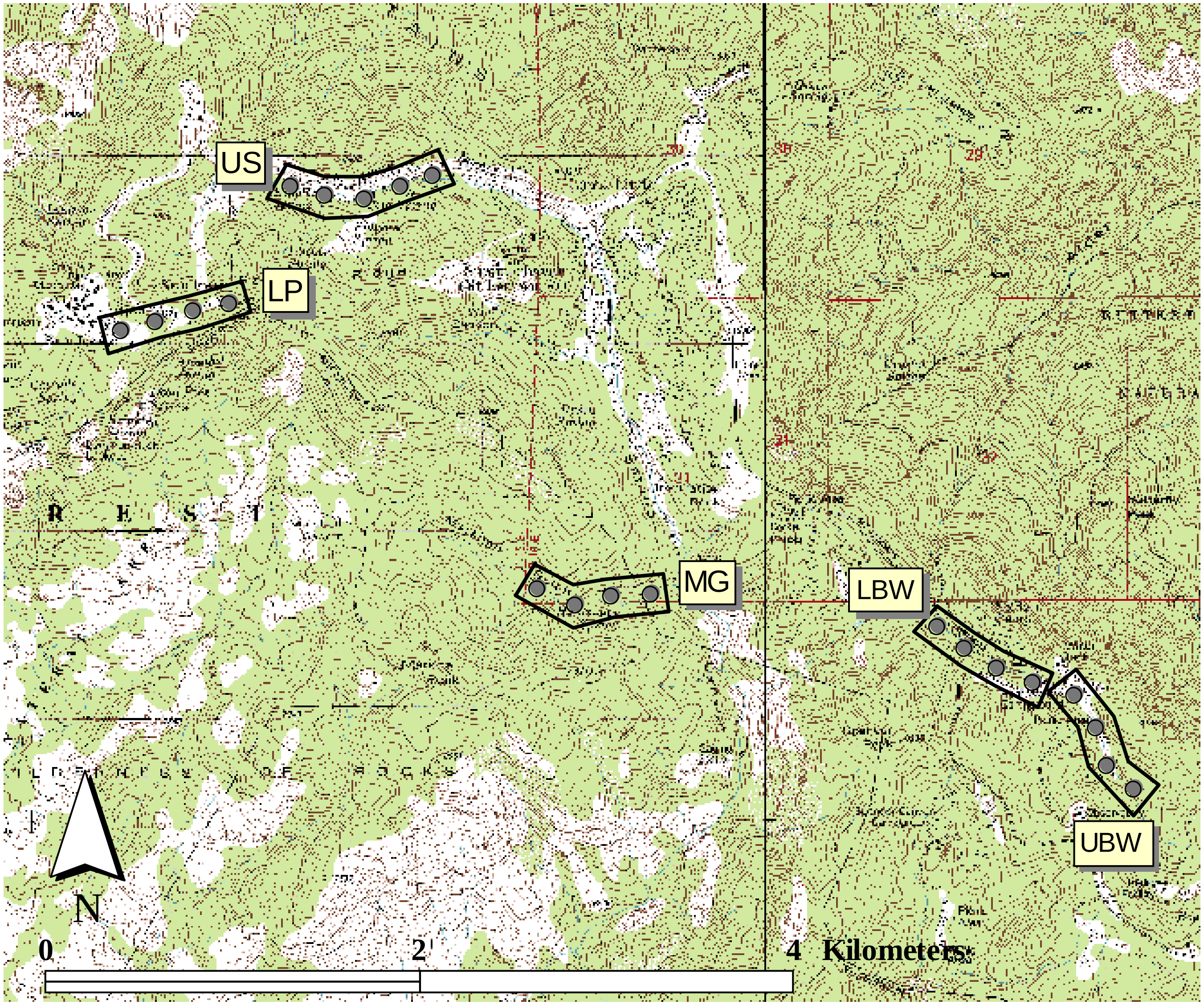

Figure 1. Map showing locations of nest search plots (polygons) and point count stations (circles) in the Santa Catalina Mountains, Arizona, 2002 and 2003. LBW = Lower Bear Wallow; LP = Lemmon Park; MG = Marshall Gulch; UBW = Upper Bear Wallow; US = Upper Sabino.

checked the four nest cameras and reviewed video tapes to determine if nests had been depredated.

DATA ANALYSIS

Reproductive success and causes of nest failures - We used data collected from nests in four of our five nest search plots to construct time lines summarizing observations from our visits to each nest. We excluded data from the Lemmon Park plot because there was very little montane riparian vegetation within this plot. Using the time lines for each nest, we estimated critical dates, determined whether the nest succeeded or failed, and quantified the total number of days under observation for each stage of the nesting cycle (see Martin et al. 1997). We rated the reliability of each time line using the following scale: 1) nest visits few and/or nest observations unreliable resulting in poor nest data and unclear critical dates; 2) nest visits more frequent and/or nest observations more reliable resulting in reasonably good nest data and critical dates; and 3) nest visits frequent with reliable nest observations resulting in reliable nest data and critical dates. We estimated initiation dates (date first egg laid) using only nests with time line reliability ratings of two or three.

For our analyses of nest success, we included nests that met the following criteria: 1) nests known (or suspected) to have succeeded by fledging at least 1 young or nests known (or suspected) to have failed; 2) nests that did not fail due to the wildfires (n = 3) or researcher disturbance (n = 5); and 3) nests of Red-faced Warblers that were not part of the separate, experimental study. For species for which we had a sufficient sample size of nests, we estimated nest success by 1) calculating apparent nest success (number of successful nests/number of nests) and 2) calculating nest success using the Mayfield method (Mayfield 1961). For the Mayfield estimates, we calculated a daily nest survival rate for the entire nest cycle (building through fledging) and, given sufficient data, the daily nest survival rates for each stage of the nest cycle.

We also calculated the total nest survival rate for each nest stage and the total nest survival rate for the entire nest cycle by adjusting estimates of daily survival rates by the average number of days in each nest stage/nest cycle (see Mayfield 1961). For these calculations, we determined the length of nest stages for several species for which we happened to observe nests on two successive critical dates (e.g., we were present on the day when eggs hatched and the day when nestlings fledged) or we used published estimates given for montane forest bird species studied previously in northern Arizona (C. Conway, unpublished data). Because no published data on the average number of days in the building period exist for some species (e.g., Cordilleran flycatcher), we estimated the length of the building stage as the average number of days (minus outliers) that we observed each species building nests.

Habitat characteristics at nests - Using data collected from nests in four of the five nest search plots (i.e., no data was used from the Lemmon Park plot), we summarized nest data for each species and compared vegetation and topographic characteristics between successful and unsuccessful nests using independent t-tests. We combined data across the four nest search plots because of our relatively small sample of nests within each plot; however, we lacked a sufficient number of nests (especially successful nests) with which to make comparisons for all but a few species.

RESULTS

Breeding biology - We found a total of 558 nests of 25 species from 2002-2004 (Table 1). In general, nests of canopy-nesting species were more difficult to locate because of the height of these nests and the presence of obstructing vegetation surrounding nests. Consequently, we found more nests of ground-nesting species (e.g., Red-faced Warbler and Yellow-eyed Junco) compared to nests of canopy-nesting species (e.g., Olive Warbler and Black-headed Grosbeak). We also spent more time looking for nests of ground-nesting birds for our related experimental study, and thus, the percentage of ground nests relative to canopy nests that we found may be biased high.

Most of the montane forest bird species for which we found nests initiated nests beginning in the first two weeks of May except Hairy Woodpecker, Northern Flicker, Mountain Chickadee, American Robin, and Yellow-eyed Junco which initiated nests starting in late-March and April and Cordilleran Flycatcher and Violet-green Swallow which initiated nest starting in late-May and June (Table 1). Few species initiated nests after mid-June and only Broad-tailed Hummingbirds, Cordilleran Flycatchers, and Hermit Thrushes were found initiating nests in July. Although sample sizes were small for some species, the average length of the nestling period was 14.5 days for American Robin (n = 1), 16 days for Cordilleran Flycatcher (n = 1), and 12.3 days (range 11-13.5) for Red-faced Warbler (n = 5). The average length of the incubation period was 14.5 days for Cordilleran Flycatcher (n = 1), 13 days for Hermit Thrush (n = 1), 12 days for Warbling Vireo (n = 1), 12.2 days (range 11-13.5) for Red-faced Warbler (n = 16), and 12.2 days (range 12-13) for Yellow-eyed Junco (n = 4). The length of the laying period was easier to estimate because it equaled the average clutch size for each species minus 1 (see Table 1). Based on our observations of nest building, we estimated the length of the building stage at nine days for Cordilleran Flycatcher and Yellow-eyed Junco and eight days for Red-faced Warbler.

Reproductive success - We estimated nest success for 13 species of montane forest birds (Table 2). As has been reported previously (Mayfield 1961), apparent nest success was higher for all species compared to nest success estimated using the Mayfield (1961) method. Our Mayfield (1961) estimates of overall nest survival were lowest for Cordilleran Flycatcher, with only 10% of nests succeeding and highest for American Robin, with 52% of nests succeeding (Table 2). Estimates of nest success were likely biased low for the building and laying periods for Red-faced Warblers because we excluded some successful nests from our analyses that were part of the related experimental study (by necessity, these nests were selected for the related experimental study because they had survived until the start of incubation). Therefore, we also calculated Mayfield (1961) nests survival estimates for the building and laying periods for Red-faced Warblers with all nests (i.e., regular and experimental nests) included in the analysis (Table 2).

Causes of nest failure and identification of common nest predators - Nest predation accounted for the greatest loss of nests during our study. Of the 208 nests known to have failed, 56% were depredated, 10% were abandoned for unknown causes, 2% were abandoned due to human disturbance, and 1% were burned during wildfires (the remaining 31% failed for unknown reasons). Excluding nests that failed due to the wildfires or human disturbance, 72% of 85 Red-faced Warbler nest failures were due to predation (30% during laying, 39% during incubation,

Table 1. Number of nests found, initiation dates, and clutch sizes for 25 species of montane forest birds in the Santa Catalina Mountains, Arizona (2002-2004). Species are listed in decreasing order of total number of nests found.

		Initiation Date[1]			Clutch Size			
Species	Total Nests	N	Mean	Range	N	Mean	SE	Range
Red-faced Warbler (*Cardellina rubrifrons*)	207	189	5/18	5/2-6/18	161	4.2	0.05	3-5
Yellow-eyed Junco (*Junco phaeonotus*)	94	80	5/14	4/16-6/29	51	3.7	0.10	2-5
Cordilleran Flycatcher (*Empidonax occidentalis*)	60	54	6/9	5/24-7/6	26	3.4	0.10	3-4
American Robin (*Turdus migratorius*)	42	22	5/12	4/25-6/20	2	3.0	-	-
House Wren (*Troglodytes aedon*)	25	11	5/25	5/3-6/22	-	-	-	-
Warbling Vireo (*Vireo gilvus*)	16	8	5/26	5/18-6/14	1	4.0	-	-
Western Tanager (*Piranga ludoviciana*)	14	6	5/29	5/15-6/25	-	-	-	-
Broad-tailed Hummingbird (*Selasphoros platycercus*)	14	7	6/3	5/3-7/14	-	-	-	-
Black-headed Grosbeak (*Pheucticus melanocephalus*)	12	7	5/22	5/9-6/15	-	-	-	-
Orange-crowned warbler (*Vermivora celata*)	10	7	5/7	4/19-5/16	7	4.5	0.20	4-5
Hermit Thrush (*Catharsus guttatus*)	13	6	5/29	5/10-7/03	4	3.8	0.25	3-4
Yellow-rumped Warbler (*Dendroica coronata*)	8	4	5/21	5/8-6/12	-	-	-	-
Plumbeous Vireo (*Vireo plumbeus*)	6	4	5/17	5/9-5/24	-	-	-	-
Mountain Chickadee (*Poecile gambeli*)	6	2	4/16	4/15-4/18	-	-	-	-
Northern Flicker (*Colaptes auratus*)	6	1	4/30	-	-	-	-	-
Hairy Woodpecker (*Picoides villosis*)	4	2	3/31	3/15-4/17	-	-	-	-
Brown Creeper (*Certhia Americana*)	4	2	5/20	5/14-5/26	-	-	-	-
Stellar's Jay (*Cyanocitta stelleri*)	4	1	6/7	-	-	-	-	-
Pygmy Nuthatch (*Sitta pygmaea*)	4	-	-	-	-	-	-	-
Spotted Towhee (*Pipilo maculates*)	2	2	5/7	5/2-5/13	-	-	-	-
Violet-green Swallow (*Tachycineta thalassina*)	2	1	6/7	-	-	-	-	-
Magnificent Hummingbird (*Eugenes fulgens*)	2	1	6/15	-	-	-	-	-
Red-breasted Nuthatch (*Sitta canadensis*)	1	1	5/7	-	-	-	-	-
Olive Warbler (*Peucedramus taeniatus*)	1	1	-	-	-	-	-	-
Hepatic Tanager (*Piranga flava*)	1	-	-	-	-	-	-	-
Total	558	-	-	-	-	-	-	-

[1] Nest initiation date based on data collected from nests with time line reliability scores of 2 or 3. All nest attempts included.

Table 2. Estimates of nest success (apparent and Mayfield [1961]) for 13 species of montane forest birds in the Santa Catalina Mountains, Arizona (2002-2004). We included only species for which we had >5 nests with known fates and limited Mayfield estimates of nest survival for each nest stage to those species with >20 nests with known fates.

			Mayfield Estimates of Nest Survival														
		Apparent Nest	Building Period			Laying Period			Incubation Period			Nestling Period			Overall (Building through Nestling Periods)		
Species	N	Success	ED[1]	Daily	Total	ED[1]	Daily	Total	ED[1]	Daily	Total	ED[1]	Daily	Total	ED[1]	Daily	Total
Broad-tailed Hummingbird	7	0.286	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cordilleran Flycatcher	43	0.258	166	0.952	0.641	66	0.864	0.693	179	0.955	0.515	201	0.955	0.480	612	0.948	0.105
House Wren	9	0.888	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hermit Thrush	6	0.166	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
American Robin	23	0.652	-	-	-	-	-	-	-	-	-	-	-	-	439	0.982	0.520
Warbling Vireo	6	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orange-crowned warbler	9	0.444	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellow-rumped Warbler	7	0.143	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-faced Warbler[2]	113	0.248	356	0.966	0.760	182	0.923	0.756	644	0.953	0.557	403	0.948	0.518	1,585	0.946	0.137
Red-faced Warbler[3]	-	-	672	0.981	0.855	401	0.925	0.762	-	-	-	-	-	-	-	-	-
Yellow-eyed Junco	69	0.609	79	0.975	0.794	30	0.864	0.685	218	0.963	0.632	414	0.976	0.746	741	0.964	0.264
Black-headed Grosbeak	8	0.625	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Western Tanager	10	0.200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[1] ED = Exposure Days (Mayfield 1961).
[2] No experimental nests included during building and laying periods (see text).
[3] Experimental nests included during building and laying periods (see text).

and 30% during the nestling stage). Seventy percent of 27 Yellow-eyed Junco nest failures were due to predation (16% during laying, 47% during incubation, and 37% during the nestling stage). Fifty-six percent of 32 Cordilleran Flycatcher nest failures were due to predation (47% during laying, 37% during incubation, and 16% during the nestling stage). Although we never observed predators taking eggs or nestlings from nests while we were in the field, we inferred that nests were depredated by the loss of eggs or nestlings before the anticipated fledge date (often accompanied by the destruction of the nest itself).

Results from our time-lapse video recordings from cameras placed at 10 ground nests revealed that five Yellow-eyed Junco nests were depredated during the spring of 2005 (Table 3). Grey Foxes (*Urocyon cinereoargenteus*) were responsible for four of the five nest depredations and an unidentified species of rat was responsible for 1 nest depredation. However, a Gray Fox also depredated this nest 24 hours after the wood rat had killed the female Junco and removed one of the three nestlings from the nest. All 6 nest depredations occurred during the night (2000 to 0218 hours).

Habitat associations - We found nests of montane forest birds in a variety of locations and at a range of heights (Table 4). For shrub and tree-nesting species, we found nests most frequently in Big Tooth Maple (*Acer grandidentatum*), Douglas Fir (*Pseudotsuga menziessi*), White Pine (*Pinus strobiformis*), and White Fir (*Abies concolor*). Our comparison of habitat characteristics between successful and unsuccessful nests (Table 5) revealed that successful Red-faced Warbler and Yellow-eyed Junco nests were associated with nest sites that offered greater nest concealment from above (i.e., nests that were located underneath leaves, bark flakes, or downed branches). In addition, successful Yellow-eyed Junco nests were associated with nest sites that had a greater density of shrub/sapling stems (average of 3 times more stems) located within a 5-m radius of the nest. We lacked a sufficient number of nests (especially successful nests) with which to compare habitat characteristics between successful and unsuccessful nests for most of the other breeding bird species present within our study area.

DISCUSSION

We were able to locate and monitor nests for most of the montane forest bird species breeding within our study area. For many of these species, however, our sample size of nests was small (<5), and consequently, our resulting estimates of clutch size, length of nest stages, reproductive success, and habitat associations should be viewed as tentative. Most of the species for which we were unable to locate nests were either species that build nests high in the forest canopy (e.g., Pine Siskin), species that are relatively uncommon within our study area (e.g., Grace's Warbler), or species that have nests that are difficult to locate (e.g., Virginia's Warbler). Further monitoring of montane forest bird populations in the Santa Catalina Mountains will allow us to locate nests of species for which we were unable to locate nests during fieldwork in 2002-2004 and increase our sample size of nests for other species. Despite small sample sizes for many species, we collected substantial data for several montane forest bird species in our study area, including two PIF Priority Species (Red-faced Warblers and Cordilleran Flycatchers). In addition, we collected some preliminary data for other PIF priority species such as Broad-tailed Hummingbird, Pygmy Nuthatch, Orange Crowned Warbler, Olive Warbler, and Western Tanager.

Table 3. Results from time-lapse video camera recordings at Yellow-eyed Junco nests showing predator species, date and time of nest depredation, and stage of nest when depredated at 4 study plots in the Santa Catalina Mountains, Arizona (May 2005).

Nest #	Plot	Species	Date	Time	Nest Stage	Comments
1	US	Grey Fox	4/27	2003	Nestling	
2	US	Grey Fox	5/1	2000	Incubation	Maybe same fox as above; nests 1 and 2 only 50 m apart.
3	LBW	Grey Fox	5/14	0137	Incubation	
4	LP	Rat (unknown sp.)	5/18	0200	Nestling	Rat kills brooding female and returns 2 hrs later for 1 nestling
4	LP	Grey Fox	5/19	0218	Nestling	Fox kills remaining 2 nestlings
5	US	Grey Fox	5/22	2306	Nestling	

Table 4. Height (mean, SE, and range) and location (plant species or substrate) of nests of 23 species of montane forest birds found in four nest search plots in the Santa Catalina Mountains, Arizona (2002-2004).

		Nest Height (m)			Nest Location (Plant Species[1] or Substrate)					
Bird Species	N	Mean	SE	Range	Primary	%	Secondary	%	Tertiary	%
Broad-tailed Hummingbird	11	8	1.2	3-17	Douglas Fir	42	Big-tooth Maple	33	Other	25
Magnificent Hummingbird	2	15	0.6	14-15	Big-tooth Maple	50	White Pine	50	-	-
Northern Flicker	4	19	4.5	11-32	Douglas Fir	50	Quaking Aspen	25	White Pine	25
Hairy Woodpecker	4	15	2.6	10-20	Quaking Aspen	50	White Fir	25	Ponderosa Pine	25
Cordilleran Flycatcher	52	1.7	0.3	0-12	Log	25	Big-tooth Maple	14	Other	61
Violet-green Swallow	1	16	-	-	Quaking Aspen	100	-	-	-	-
Stellar's Jay	2	12	1	11-13	White Fir	50	White Pine	50	-	-
Mountain Chickadee	6	12	1.5	8-19	Quaking Aspen	50	White fir	50	-	-
Brown Creeper	4	7	1.1	4-9	Conifer Snag	75	White Fir	25	-	-
Pygmy Nuthatch	3	14	1.6	12-17	Fir Snag	67	Ponderosa Pine	33	-	-
House Wren	20	4	0.4	2-7	Big-tooth Maple	62	Quaking Aspen	10	Other	28
Hermit Thrush	9	3	0.5	0.5-6	White Pine	22	Big-tooth Maple	22	White Fir	22
American Robin	32	7	0.7	2-16	Big-tooth Maple	32	White Pine	20	Other	68
Plumbeous Vireo	6	7	1.5	3-13	Big-tooth Maple	83	White Fir	17	-	-
Warbling Vireo	14	11	1.9	4-28	Big-tooth Maple	64	Arizona Alder	14	Quaking Aspen	14
Orange-crowned Warbler	3	0	-	-	Ground	-	-	-	-	-
Red-faced Warbler	157	0	-	-	Ground	100	-	-	-	-
Yellow-rumped Warbler	6	9	2.3	3-15	Douglas Fir	50	Big-tooth Maple	33	White Pine	17
Olive Warbler	1	26	-	-	White Pine	100	-	-	-	-
Black-headed Grosbeak	10	10	1.6	4-21	Douglas Fir	30	White Pine	30	White Fir	30
Yellow-eyed Junco	72	0.2	0.2	0-10	Ground	98	Fir Snag	1	White Fir	1
Hepatic Tanager	1	5.8	-	-	White Fir	100	-	-	-	-
Western Tanager	11	14	2.2	2-25	Douglas Fir	33	White Pine	33	Other	34

[1] Scientific names of plant species not mentioned in text: Mountain Snowberry (*Symphorocarpu oreophilus*); Ponderosa Pine (*Pinus ponderosa*); Quaking Aspen (*Populas tremuloides*); Arizona Alder (*Alnus oblongifolia*).

Table 5. Comparison of habitat characteristics at successful (S) and unsuccessful (U) nests of 3 montane forest bird species in the Santa Catalina Mountains, Arizona (2002-2004). Counts of shrub/sapling stems (measured at 10-cm) were made within an 5-m radius plot centered on the nest.

			Slope (degrees)		% Side Nest Concealment		% Overhead Nest Concealment		% Canopy Cover		Shrub/Sapling Stems <2.5 cm		Shrub/Sapling Stems 2.5-8 cm	
Species	Fate	N	0	SE	0	SE	0	SE	0	SE	0	SE	0	SE
American Robin	S	8	23	3.9	-	-	-	-	78	7.4	-	-	-	-
	U	26	17	1.8	-	-	-	-	86	2.5	-	-	-	-
Red-faced Warbler	S	11	22	2.6	77	5.7	90[2]	4.2	78	3.6	35	10.3	6	1.5
	U	114	27	1.0	82	1.4	82[2]	2.3	80	1.7	27	2.9	7	0.6
Yellow-eyed Junco	S	22	27	3.9	86	3.2	90[1]	3.6	72	4.6	46	9.9	6[1]	1.6
	U	51	22	1.7	86	1.6	77[1]	4.1	65	4.5	32	7.8	2[1]	0.7

[1] Estimates for successful nests significantly different from estimates for unsuccessful nests at the $P < 0.05$ level.
[2] Estimates for successful nests significantly different from estimates for unsuccessful nests at the $P < 0.10$ level.

High rates of nest failure (resulting primarily from high rates of nest predation) were common for populations of several montane forest bird species in our study area. Overall nest success (calculated using the Mayfield [1961] method) was low for Cordilleran Flycatcher, Red-faced Warbler, and Yellow-eyed Junco. The overall rate of nest survival for Red-faced Warblers observed during the current study was only 14%; lower than overall nest survival rates reported from previous studies in Arizona (Martin and Barber 1995). Similarly, the overall rate of nest survival for Cordilleran flycatchers was lower in our study area (11%) compared to overall nest survival rates reported for Cordilleran Flycatchers elsewhere in Arizona (Lowther 2000). Most nest failures for these two species were a result of nest predators. Red-faced Warblers and Cordilleran Flycatchers are locally abundant in our study area (Kirkpatrick et al. 2004); however, the low rates of nest success observed during the current study may be cause for concern. We need to continue monitoring these populations to determine whether the high rates of nest predation observed from 2002-2004 are indicative of a long-term pattern or simply a short-term aberration.

Results from time-lapse video recordings from cameras placed at ground nests revealed that nests of Yellow-eyed Juncos were depredated by mammalian predators (primarily Grey Foxes). Although our data are limited, we infer that other ground-nesting birds that nest in close proximity to Yellow-eyed Juncos (e.g., Red-faced Warblers and Orange-crowned Warblers) may also be susceptible to the same mammalian nest predators. However, we suspect that other species of nest predators (e.g., Stellar's Jays) may also be responsible for nest depredations within our study area. We will continue to monitor ground nests with time-lapse video cameras to increase our sample size of depredated nests and identify other species of nest predators. Our comparison of habitat characteristics between successful and unsuccessful nests showed that successful Red-faced Warbler and Yellow-eyed Junco nests were associated with nest sites that offered greater nest concealment from above. In other words, nest that were located underneath concealing material such as leaves, grass, roots, or dead ferns where more likely to succeed than nests that were exposed from above. Increased nest concealment likely confers a greater degree of protection from nest predators.

MANAGEMENT IMPLICATIONS AND FUTURE RESEARCH

Data collected during the current study provide a framework with which to continue monitoring montane forest bird populations in the Santa Catalina Mountains, including populations of several PIF Priority Species. Our results for species such as Red-faced Warblers and Yellow-eyed Juncos show that we can obtain the necessary data for effective, long-term monitoring of these species (i.e., estimates of reproductive success and measurements of habitat data; Ralph et al. 1993). Given more time and increased sample sizes, we will be able to compare habitat characteristics between successful and unsuccessful nests for many other species. Ultimately, data from this project will provide important information with which to better manage and conserve populations of montane forest birds in Arizona. Further research is needed to determine whether the low nest success rates that we observed for some species during the current study are representative or simply reflect increased rates of nest failure from 2002-2004. Previous studies have shown that predation rates are higher for Yellow-eyed Juncos during drought years in southeastern Arizona (Sullivan 1999). 2002, 2003, and 2003 were extreme drought years in Arizona and dry conditions and/or increased nest predation pressure may have contributed to the relatively low nest success rates that we observed. In addition, we need to identify additional nest predators and determine the frequency with which each nest predator species depredates nests. By increasing our understanding of the role that predators play in the reproductive success of birds, we will be better able to manage and conserve populations of montane forest birds in Arizona.

ACKNOWLEDGEMENTS

This project was funded by the Arizona Bird Conservation Initiative, the Arizona Game and Fish Department, T & E, Inc., and the University of Arizona. S. Sferra and the Bureau of Reclamation generously provided use of time-lapse video cameras. We thank M. Ali, D. Fox, G. Gryniewicz, K. Hughes, D. Holstein-Radin, D. LaRoche, E. Martinez-Leyva, E. Nolte, A. Purdy, E. Rose, C. Seal, D. Tracy, and A. Westling-Douglass for assistance with fieldwork. We also thank B. Stolp, and J. Taiz (Coronado National Forest) for assistance with access to our study area. B. Peterson and the University of Arizona Steward Observatory provided field housing.

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