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Nest Predators of Ground-nesting Birds in Montane Forest of the Santa Catalina Mountains, Arizona

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ABSTRACT.—We used time-lapse video cameras and track plates to identify nest predators of Red-faced Warblers (*Cardellina rubrifrons*) and Yellow-eyed Juncos (*Junco phaeonotus*) in high-elevation (> 2,300 m) forests of the Santa Catalina Mountains in southeastern Arizona. Mammals, especially gray fox (*Urocyon cinereoargenteus*) and cliff chipmunk (*Tamias dorsalis*), were the principal nest predators of Red-faced Warblers and Yellow-eyed Juncos within our study system, accounting for 89% of all nest depredations. Our study is one of the first to use video cameras at real nests to document the prevalence of nest predators in montane forest ecosystems. Additional research is needed to learn if mammals are the dominant nest predators in other montane environments. *Received 23 October 2009. Accepted 24 March 2010.*

Nest depredation is the most common cause of reproductive failure of small land birds (Ricklefs 1969, Martin 1992). However, we lack reliable data on the identity and relative importance of nest predator species for most birds (Thompson 2007). Information on nest predators is particularly sparse for birds that breed in high-elevation (>2,300 m) forests in sky island mountain ranges of the southwestern United States. For example, ≥89% of nest failures of ground-nesting birds in high-elevation forests of the Santa Catalina Mountains in southeastern Arizona is attributed to nest depredation (Kirkpatrick and Conway 2010). However, the identity of even the most common nest predators remains unknown. Identification of nest predators is a critical first step in managing breeding populations of birds and in discerning how nest depredation shapes nest-site selection, life history strategies, and breeding behavior in birds (Weatherhead and Blouin-Demers 2004, Thompson 2007).

We used time-lapse video cameras (henceforth ''video cameras'') to monitor nests of Red-faced Warblers (*Cardellina rubrifrons*) and Yellow-eyed Juncos (*Junco phaeonotus*) in montane forests of the Santa Catalina Mountains in southeastern Arizona. Use of video cameras to monitor bird nests provides a reliable method to identify common nest predators (McQuillen and Brewer 2000, Williams and Wood 2002), but the technology is expensive and labor intensive and often only a small sample of nests can be monitored (Thompson 2007). We augmented video camera monitoring with track plates (Wilson and Delahay 2001) to identify potential nest predator species within our study system.

METHODS

Study Area.—We conducted research in five 16–20 ha study plots (2,300–2,800 m elevation) within several forested drainages (Kirkpatrick and Conway 2010) and one forested ridge (Kirkpatrick and Conway 2005) in the Santa Catalina Mountains, Pima County, Arizona, USA. Temperatures within our study area varied from an average of 6.5° C in mid-April to an average of 17.6° C in mid-July (Decker and Conway 2009).

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Nest Monitoring.—We searched for and monitored nests of Red-faced Warblers and Yellow-eyed Juncos in our five study plots from late April to mid-July in 2005–2006. Red-faced warblers and Yellow-eyed Juncos are the two most common ground-nesting birds within our study area: they breed concurrently, share similar nest-site characteristics, and nest in close association (Kirkpatrick and Conway 2010). Thus, we were reasonably confident that nests of both species would be susceptible to the same community of nest predators.

Video Cameras.—We monitored 16 Red-faced Warbler and 23 Yellow-eyed Junco nests with continuously-operated, time-lapse (5 frames/sec), video cameras equipped with infrared illumination for night-time photography (Fieldcam TLV, Fuhrman Diversified Inc., Seabrook, TX, USA; McQuillen and Brewer 2000). The nesting stage at which we first set out video cameras at nests varied: building (19% of nests), egg laying (12%), incubation (54%), and nestling (15%). We attached a small (5 × 2 × 2 cm) camera via a small articulated arm to a small wooden stake buried in the ground ~ 1 m from the nest and positioned the camera so that it was 40–60 cm from the nest. We concealed the camera and its articulated arm with camouflage fabric and ran a cable (hidden under leaf litter) > 15 m from the video camera to a concealed location where we placed the video recorder and battery.

We visited each video recorder every 24 hrs to change video tapes and batteries, and to check the status of the nest remotely with a hand-held video monitor. We occasionally approached nests along a defined trail to verify nest contents or to adjust cameras. We made no effort to mask our scent trail during these nest checks. Human scent trails leading to artificial ground nests in our study area did not increase the probability of nest depredation (Kirkpatrick and Conway 2009). We left video cameras at nests until young fledged or nests failed; we then reviewed video tapes of all depredated nests to identify the species of nest predator and the date and time of each depredation event. We assumed that multiple visits to a nest by the same predator species were the result of a single individual of that species.

Track Plates.—We placed 38 track plates at 100-m intervals along the center of four of our five study plots during the middle of the bird breeding season (3 Jun 2007), alternating locations of the track plates from one side of the drainage to the other. We placed the plates on relatively flat ground at a random distance <50 m from the drainage bottom ($\bar{x}$ ± SD: 26 ± 10 m). We chose a 50-m distance interval because Red-faced Warblers and Yellow-eyed Juncos select nest sites that average 26 and 21 m, respectively, from drainage bottoms within our study area (Kirkpatrick and Conway 2010).

We used a protocol similar to Cain (2001) to construct track plates from galvanized steel sheeting (60 × 91 cm) and taped a piece of contact paper (30 × 46 cm) to the middle of each plate. We sprayed a mixture containing two parts isopropyl alcohol and one part blue carpenter's chalk (Drennan et al. 1998) on the track plate around the contact paper and placed a Japanese Quail (*Coturnix japonica*) egg covered in chicken (*Gallus gallus*) egg yolk on the center of the contact paper. We calculated an index of predator activity based on the percentage of the 38 track plates that had ≥1 identifiable track of a predator species following a 6-day exposure period (Drennan et al. 1998).

RESULTS

Video Cameras.—Nineteen of 39 nests with video cameras were successful, 17 were depredated (total of 18 depredation events; Table 1), two were abandoned due to inclement weather, and one was abandoned for an unknown reason. Both Red-faced Warbler and Yellow-eyed Junco nests were depredated by gray foxes (*Urocyon cinereoargenteus*), cliff chipmunks (*Tamias dorsalis*), and Steller's Jays (*Cyanocitta stelleri*). One Yellow-eyed Junco nest was depredated partially by a gray fox and a woodrat (likely *Neotoma mexicana*). Gray foxes and the woodrat depredated nests at night (67% of all nest depredation events), whereas cliff chipmunks and Steller's Jays depredated nests during the day (33% of all nest depredation events; Table 1). Gray foxes depredated video camera nests both early and later in the avian breeding season (27 Apr–19 Jul), whereas cliff chipmunks depredated video camera nests only later in the season (1 Jun–1 Jul).

Track Plates.—We identified tracks of six mammal and one bird species on track plates in early June 2007. Indices of predator activity were 50% for gray fox, 32% for mice (*Peromyscus* spp.), 32% for cliff chipmunk, 8% for Abert's squirrel (*Sciurus aberti*), 5% for Steller's Jay, 3% for bobcat (*Lynx rufus*), and 3% for domestic dog (*Canis lupus familiaris*). Pilot work using track

TABLE 1. Depredation events at Red-faced Warbler and Yellow-eyed Junco video camera nests by four nest predator species in high-elevation (>2,300 m) forest within the Santa Catalina Mountains, Arizona (late Apr to mid Jul, 2005–2006).

Nest predator	Depredation events			Time range (hrs) of depredations[a]
	Red-faced Warbler nests	Yellow-eyed Junco nests	Totals	
Gray fox	3	8	11	2004–0330
Cliff chipmunk	2	2	4	0645–1911
Steller's Jay	1	1	2	0800–1551
Woodrat[b]	0	1	1	0200–0420[c]
Totals	6	12	18	

[a] Mountain Standard Time.
[b] Likely *N. mexicana* (Kirkpatrick and Conway 2006).
[c] A woodrat depredated the brooding female Yellow-eyed Junco at 0200 hrs and then returned to the nest to depredate one of three nestlings at 0420 hrs. A gray fox depredated the two remaining nestlings (which were still alive) at 0218 hrs the next day (Kirkpatrick and Conway 2006).

plates in early May 2007 also recorded rock squirrel (*Spermophilus variegatus*) and Common Raven (*Corvus corax*) within our study area (C. Kirkpatrick, unpubl. data).

DISCUSSION

Mammals, especially gray fox and cliff chipmunk, were the principal predators of Red-faced Warbler and Yellow-eyed Junco nests within our study system, accounting for 89% of all nest depredations documented on video. Gray fox and cliff chipmunk are common in montane forests throughout southeastern Arizona (Hoffmeister 1956, Lange 1960) and are known to depredate bird nests (Burt and Grossenheider 1976, Hart 1992). Other potential mammalian nest predators, including mice, Abert's squirrels, bobcats, domestic dogs, and rock squirrels were present within our study area (documented by track plates and visual observations by field personnel) but were not recorded depredating nests by video cameras (perhaps because some of these species occur at low densities; C. Kirkpatrick, pers. obs.).

Additional video camera monitoring may be necessary to ascertain whether some of these mammals (especially mice; Bradley and Marzluff 2003, King and DeGraaf 2006) are occasional nest predators within our study system. Some nest predators may avoid or be attracted to nests with video cameras and the track plates provide a means by which one can identify nest predators present in the study system that were not captured by video surveillance. Data from track plates do not provide an unbiased estimate of density or movement rates of nest predators because they are baited and some predators may avoid or be attracted to them, but they do provide information on the suite of potential nest predators and their relative levels of activity (relative to other locations where track plates are placed with similar methods).

The prevalence of mammalian nest predators in our study system is surprising given that snakes are considered to be the principal nest predator of many New World passerine birds (Weatherhead and Blouin-Demers 2004), especially in the southern USA (Thompson 2007). We believe we did not record snakes as nest predators because our study area was: (1) >2,300 m above sea level in an environment thermally inhospitable to most snake species (M. J. Goode, University of Arizona, pers. comm.); and (2) beyond the northern range limits of several montane rattlesnake species (Stebbins 1985), one of which (twin-spotted rattlesnake [*Crotalus pricei*]) is known to occasionally depredate Yellow-eyed Junco nests at high elevation (2,560 m; Gumbart and Sullivan 1990). We observed only two snakes (Sonoran mountain kingsnake [*Lampropeltis pyromelana*] and Arizona black rattlesnake [*Crotalus cerberus*]) near our study plots and none within the boundaries of our study plots despite thousands of person hours in the field from 2002 to 2009 (C. Kirkpatrick, unpubl. data).

Our study is one of the first to use video cameras at real nests to identify nest predators and measure their relative importance in montane forest ecosystems (similar results were obtained in montane forests of northern Arizona where mammals caused 62% of diurnal nest depredations; T. E. Martin, University of Montana, pers. comm.). Additional research is needed to ascertain if mammals are the principal nest predators in other high-elevation environments. Selection should favor adaptations by birds to reduce exposure to numerous olfactory-oriented, nocturnal nest predators (e.g., gray foxes, woodrats, mice) in montane environments, just as selection is thought to favor behaviors that reduce exposure to visually-oriented, diurnal predators in other ecosystems (Weatherhead and Blouin-Demers 2004). Identifying the commonalities in the suite of primary nest predators within different ecosystems may help explain differences in behavior and life history traits among species of birds. Montane forests in the Santa Catalina Mountains provide an ideal environment to examine these issues given that breeding populations of ground-nesting birds at higher elevations (>2,300 m) are contiguous with breeding populations at lower-elevations (>1,800 m) where snakes and other nest predators are likely to be more common.

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