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ONE YEAR OF MIGRATION DATA FOR A WESTERN YELLOW-BILLED CUCKOO

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ABSTRACT: In 2009, we studied the migration of the Western Yellow-billed Cuckoo by capturing 13 breeding birds on the middle Rio Grande, New Mexico, and attaching a 1.5-g Mk 14-S British Antarctic Survey geolocator to each bird. In 2010, we recaptured one of the cuckoos, enabling us to download its geolocation data. The cuckoo had flown approximately 9500 km during its southward migration, traveling through Central America to winter in portions of Bolivia, Brazil, Paraguay, and Argentina. The spring migration route differed somewhat from the fall route, with the cuckoo bypassing Central America to migrate through the Caribbean. Additionally, it moved between New Mexico and Mexico at the end of summer in 2009 and again in 2010 before being recaptured at its breeding site. Our results, albeit from one individual, hint at a dynamic migration strategy and have broad implications for the ecology and conservation of the Western Yellow-billed Cuckoo, a species of conservation concern.

Increasingly, researchers are focusing on understanding the ecology and conservation of migratory birds across their entire annual cycle (Webster et al. 2002). Yet documenting the movement patterns of migratory landbirds, and thus where they occur at different times of the year, has proven difficult (Rappole and Ramos 1994, Rappole 1995). Direct methods of tracking have historically relied on techniques such as banding, requiring large numbers of individuals to be marked for a small percentage return (e.g., Norris et al. 2006, Rodriguez et al. 2009); radar, which does not provide information on individuals (Gauthreaux 1971); satellite tracking, which is expensive and

the devices are currently too heavy to be used on most landbirds (Ueta and Higuchi 2002, Hobson 2008); or radio telemetry, which presents logistical difficulty in transmission of data over long distances (Kenward 2001).

Recently, miniaturized light-level geolocators have become an important tool in the study of avian migration, especially with seabirds (Phillips et al. 2004, Mackley et al. 2010), but increasingly with landbirds as the technology becomes further miniaturized (Rodriguez et al. 2009, Stutchbury et al. 2009, Bächler et al. 2010). Light-level geolocation is the calculation of position from readings of ambient light levels (measuring day length and times of sunrise and sunset to estimate longitude and latitude, respectively) with reference to time (Fox 2010). Studies using geolocators are just now beginning to be published (see BAS 2011) and are providing important insights into migratory birds' entire annual cycle, including a better understanding of winter ranges and migration routes (Stutchbury et al. 2009, Heckscher et al. 2011) and information on connectivity between winter and breeding ranges (Ryder et al. 2011).

The Yellow-billed Cuckoo (*Coccyzus americanus*) is suffering population declines in both the eastern and western portions of its range (Laymon and Halterman 1987, Sauer and Droege 1992, DeSante and George 1994, Hughes 1999); however, declines in the West have been severe, and listing of the western subspecies (*C. a. occidentalis*) under the Endangered Species Act is warranted but reportedly "precluded by higher listing priorities" (USFWS 2001). Data on the ecology and conservation needs of breeding Western Yellow-billed Cuckoos are sparse, but studies in California (Laymon et al. 1997), Arizona (Johnson et al. 2008, Halterman 2009, McNeil et al. 2010), New Mexico (Sechrist et al. 2009, Ahlers et al. 2010), and northern Mexico (Rohwer et al. 2009) have recently provided important insights into their ecology, habitat requirements, and potential threats on the breeding grounds. In contrast, virtually nothing is known of the cuckoo's migration and winter ecology (Hughes 1999). In 2009, we placed geolocators on 13 Yellow-billed Cuckoos in central New Mexico. The following summer (2010) we recaptured and retrieved the geolocator from one of these individuals. Although from a single bird, the data presented here (1) are the first to document the species' movements over an annual cycle, (2) contradict the suggestion (Laymon 2000) that the western subspecies winters west of the Andes Mountains and does not migrate through the Caribbean (Hughes 1999), and (3) reveal heretofore unknown seasonal movements within the breeding range that may be related, among other things, to molt, dual nesting, or possibly facultative brood parasitism (Nolan and Thompson 1975, Pyle et al. 2009, Rohwer et al. 2009).

METHODS

In 2009, using mist nets and broadcast calls (Halterman 2009), we captured 13 Yellow-billed Cuckoos near Elephant Butte Reservoir on the middle Rio Grande in central New Mexico (33.458° N, 107.176° W). The cuckoos were banded, measured (after Sechrist et al. 2009), and fitted with an archival light-level geolocator (model Mk 14-S at 1.5 g, British Antarctic Survey

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[BAS], Cambridge, England; Figure 1). We determined the birds' breeding status by the presence of a brood patch or palpation of eggs. We attached the geolocators with a Rappole and Tipton (1991) leg-loop harness, scaling the loop's size to the bird's mass (Naef-Daenzer 2007); geolocators averaged 2.5% of the bird's mass at capture. With the instrument attached, the birds were released at their sites of capture, then in 2010 we revisited these sites—and nearby areas where surveys had detected cuckoos—in an effort to recapture them. Yellow-billed Cuckoos have large home ranges, averaging 52–62 ha (Halterman 2009, Sechrist et al. 2009; 95% fixed-kernel home range), and their detectability is low (approximately 32% in tape-playback surveys; Halterman 2009). Despite intensive efforts, we recaptured only 1 of 13 birds (8%). This seemingly low rate is, however, comparable to the 10% (5 of 52 marked birds) rate of site fidelity Halterman (2009) reported from a long-term study in Arizona of cuckoos that were banded but did not carry geolocators. Furthermore, we saw no indication of lower-than-normal return rates due to effects of the geolocators (Bowlin et al. 2010).

We used the BASTrak (BAS) suite of software and a standard method (e.g., Heckscher et al. 2011) of analysis of the geolocator data, a single-threshold technique, which equates a certain sun elevation with a certain light level). We calibrated the retrieved geolocator under an open sky, and the comparison of the open calibration data with the known site of deployment indicated the data points were shifted south by approximately 3° (J. Fox pers. comm.); this shift is likely due to heavy shading consistent with the riparian overstory along the middle Rio Grande and, presumably, the



Figure 1. Yellow-billed Cuckoo with geolocator attached.

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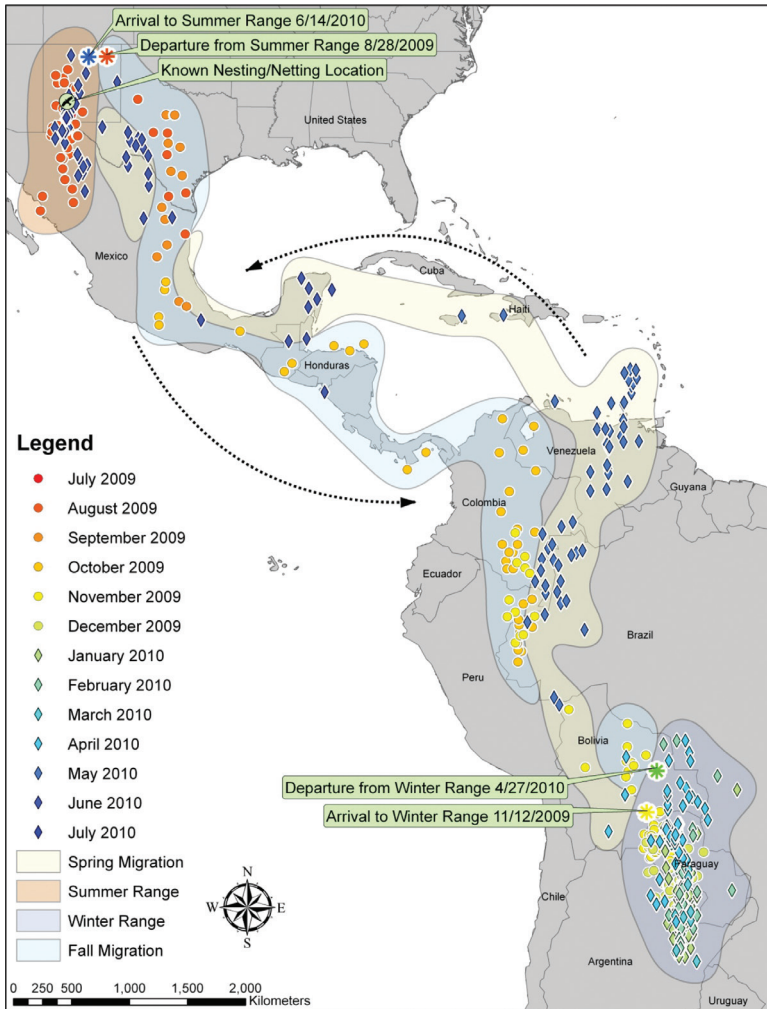


Figure 2. Locations of a Yellow-billed Cuckoo inferred from a geolocator deployed from 31 July 2009 to 2 July 2010. Location shapes (year) and colors (month) are coded to reflect the species' annual cycle. To account for inherent uncertainty in exact locations, polygons encompass a buffered area 200 km wide around locations (see text).

bird's habitats in migration and winter. We corrected for the heavy vegetation shading in BASTrak by selecting a light-level threshold value of 2, corresponding to a solar elevation angle of -4° . After this correction, we assigned confidence levels to the data on the basis of an equinox timeline (confidence values decreasing as the date approaches the equinoxes, when

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day and night are of equal length at all latitudes) and obviously anomalous transitions (e.g., a lower confidence value if points were more than 80 km from land); only data with confidence values of 9 (on a scale of 0 to 9) were used. The accuracy of geolocators is generally estimated at ± 150 km, but it varies depending on the proximity to solstices and equinoxes, with periods around the autumnal and vernal equinoxes providing poor resolution (Fudickar et al. 2011). Therefore, we excluded from our analysis latitude data within 15 days of the equinoxes (Hill 1994).

We then calculated migration routes and wintering areas from the post-processed BASTrak latitude and longitude data. We applied a conservative 200-km buffer or “area of potential uncertainty” to all calculated positions in order to accommodate known error associated with calculation of positions from geolocator data (see Phillips et al. 2004, Bächler et al. 2010, Fudickar et al. 2011). We smoothed the tracks by means of a polynomial approximation with an exponential kernel-smoothing algorithm with a 300-m tolerance in ArcGIS (ESRI, Inc.). Then we used these buffered tracks to visually assist in the interpretation of movement patterns, migration routes, and approximate area of error. Range and migration routes were shaded and delineated on the basis of the date stamp.

RESULTS

We retrieved the lone geolocator from a female cuckoo on 2 July 2010, approximately 1.4 km from the site of its initial capture on 31 July 2009 south of Socorro, New Mexico. The bird was healthy, vocal (before capture), and there was no visible injury from the harness or the geolocator unit. Its mass was barely changed, being 4% less than its 2009 weight of 60 g. We removed the geolocator immediately for downloading and analysis of the data.

The geolocator’s position data may be categorized broadly by the phases of the annual cycle (breeding, wintering, and migration; Figure 2). The total distance from the calculated northwesternmost position in New Mexico to the southeasternmost positions in Argentina was approximately 9500 km. The distance from the centroid of the summer range to the centroid of the winter range was approximately 8800 km.

Summer 2009 (31 July 2009–28 August 2009)

After the instrument was attached on 31 July 2009 the bird left the middle Rio Grande on or about 20 August 2009 and entered Mexico, moving through the states of Chihuahua and Sonora over a 7-day period. It then returned to New Mexico, apparently using the Rio Grande prior to beginning fall migration (Figure 2). During this period the bird moved possibly as much as 1050 km, as estimated from the greatest straight-line distance between locations during this period.

Fall 2009 (28 August–12 November 2009)

The cuckoo began fall migration by moving from New Mexico east into Texas on 28 August 2009 (Figure 2). It may have followed the Canadian River to the Brazos or portions of the Colorado River while traveling through Texas to reach the Caribbean slope of Mexico in early September. In Mexico,

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before the equinox, it visited the states of Nuevo Leon, San Luis Potosí, Tamaulipas, and possibly Tlaxcala. After the equinox (early October) it moved through the Mexican states of Queretaro, Hidalgo, and Guerrero. It then traveled through Central America and arrived in northern Colombia on or about 18 October 2009. By mid-November, the bird had traveled south along the east side of the Andes through central Colombia, northeastern Peru, western Brazil, and western Bolivia (Figure 2). The overall estimated maximum distance traveled during fall migration was 7250 km. The minimum estimated migration rate (maximum distance traversed divided by estimated numbers of travel days) was 94 km/day.

Winter 2009/2010 (12 November 2009–27 April 2010)

The cuckoo spent more than 5 months in a winter range that encompassed parts of Bolivia, Brazil, Paraguay, and Argentina (Figure 2). The estimated maximum distance it traveled during this period was 1050 km.

Spring 2010 (27 April–14 June 2010)

The cuckoo's spring migration apparently began in Bolivia but generally passed to the east of the fall route. The bird moved through western Brazil and eastern Colombia, then reached central Venezuela by mid-May. It apparently island-hopped through the eastern Caribbean, traveling north from Trinidad and just west of the Lesser Antilles, then west through Haiti, Jamaica, and the Cayman Islands (Figure 2). It apparently arrived at the Mexican state of Yucatan on 1 June 2010, then within 5 days began migrating north through Veracruz (Figure 2). It entered southwestern Texas on or about 10 June 2010 and apparently followed the Pecos River to New Mexico. It may have briefly used the Canadian River and its tributaries to reach the upper and middle Rio Grande by mid-June. The estimated overall maximum distance traveled during spring migration was 7750 km during 49 days of migration, for an estimated minimum migration rate of 158 km/day.

Summer 2010 (14 June–2 July 2010)

The cuckoo did not immediately establish a territory upon arriving at the middle Rio Grande; instead, it appears to have traveled through New Mexico into the Mexican state of Chihuahua—possibly along the Conchos River or its tributaries—over 9 days (22 June–30 June, Figure 2). The bird returned to New Mexico on or about 30 June 2010 and was recaptured on the middle Rio Grande 2 July 2010, only 1.4 km from the location of its initial capture in 2010. Overall estimated distance traveled between 14 June and 2 July was 1000 km.

DISCUSSION

Our results, albeit from one individual, hint at a flexible migration strategy and have broad implications for the ecology and conservation of the cuckoo. Western populations of the Yellow-billed Cuckoo are in decline (Laymon and Halterman 1987, Hughes 1999, Laymon 2000). Efforts to monitor breeding populations at several western sites are continuing, but these studies provide data relevant to only the reproductive portion of the species' life cycle. The use

of geolocators to monitor migration routes, to identify the location of stopover sites and winter ranges, and to measure the length of stopover has obvious and immediate utility for the management and conservation of this species and other migrants (Rodriguez et al. 2009, Stutchbury et al. 2009, Bächler et al. 2010). Although geolocators can provide only a broad picture of location and habitat use because of the error currently associated with this method (Fudickar et al. 2011), the broad-scale geographic information that our recaptured cuckoo provided raises some interesting questions that we think deserve further study.

Subspecific Differences in Migration Routes and Winter Ranges?

The extent to which the two subspecies of the Yellow-billed Cuckoo use the same migration corridors, or whether their winter ranges overlap, is unclear. Hughes (1999) and Laymon (2000) speculated that the eastern and western subspecies have distinctive, discrete migratory routes and winter ranges with the southward migration of the western subspecies passing along the Pacific slope of western Mexico and Central America to a winter range in northwestern Costa Rica, southern Panama, and along the west slope of the Andes in Columbia, Ecuador, and possibly Peru. In contrast, they suggested the southward migration of the eastern subspecies (*C. a. americanus*) to pass through the islands of the Caribbean south through northeastern South America to a winter range east of the Andes from Venezuela, Guyana, and Surinam south to southern Brazil, Paraguay, Uruguay, and northern Argentina. Additionally, Hughes (1999) compiled evidence that migrants on Caribbean islands are primarily *C. a. americanus*, in both spring and fall. Despite our cuckoo breeding on the middle Rio Grande (as attested by a brood patch in both years) within the putative range of *C. a. occidentalis*, its migration pattern (Figure 2) suggested that of *C. a. americanus* since it wintered south of the Amazon Basin and used a Caribbean route north in the spring. Clearly more study is needed to reveal whether this one individual's migratory path reflects that of the western subspecies; nonetheless, its route suggests a migration strategy more complex than previously understood.

Significance of the Breeding-Range Movements into Mexico?

In the summer of both 2009 and 2010 the cuckoo moved from its presumed site of breeding in New Mexico south about 1000 km into Mexico before returning north to New Mexico. This movement appears to be real and directed, as it far exceeds the geocator's position error of 150–200 km (Fudickar et al. 2011). We can think of several possible explanations for such movement. The first, described by Rohwer et al. (2009) as “migratory double breeding,” involves birds that breed in the United States and then, after their first round of breeding, migrate long distances south, where they breed a second time. The Yellow-billed Cuckoo was one of several species Rohwer et al. (2009) suggested to have such a strategy. In 2009 our cuckoo flew south into Mexico near the end of the period in which it is considered resident in central New Mexico (Hunter et al. 1985, Sechrist et al. 2009) and spent 7 days (20–26 August) in Chihuahua and Sonora before returning to New Mexico to begin fall migration. On 14 June 2010, it returned to its site of breeding in 2009 but a week later flew south back into Chihuahua, where it resided for about a week before returning north to New Mexico on or about 30 June.

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Although we do not believe this female remained in northern Mexico long enough for double breeding in either year (assuming a 17-day nesting cycle, Hughes 1999), we cannot discount the possibility that directed movement of this type may facilitate a double breeding by some individuals in some years.

Another possible explanation for this unusual movement may be related to molt migration, that is, the movement of birds from more northern parts of North America into northern Mexico to avail themselves of the seasonal flush of vegetation and arthropods associated with the monsoon season (Pyle et al. 2009). Our bird obviously could not have molted in the short periods it was away from its site of breeding area, and the Yellow-billed Cuckoo's prebasic molt is not reported to begin until September (Hughes 1999). It could, however, have used these flights to prospect for suitable habitat and conditions where it could undergo molt at the appropriate time.

Finally, the Yellow-billed Cuckoo is suspected of engaging in both intra- and interspecific brood parasitism, especially during times of abundant food (Nolan and Thompson 1975, Fleischer et al. 1985, Hughes 1999). Nolan and Thompson (1975) speculated that it may parasitize occasionally as an evolutionary mechanism that permits very quick exploitation of sporadically abundant food. Prospecting for such ephemeral resources, coupled with a flexible reproductive strategy in the form of facultative brood parasitism, could favor movements over large areas to identify areas of seasonally or locally abundant food.

The limited information we have, while not supporting a cause for any one scenario, does indicate a connection between cuckoos occurring on the middle Rio Grande in New Mexico and those in the Mexican states of Chihuahua and Sonora. But clearly more information is needed for an understanding of the significance of this connection and its implications for the conservation of the western population of the species.

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