ANNUAL REPORT:

ECOLOGY AND SEASONAL MOVEMENTS OF MANGROVE CUCKOOS

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SUMMARY

We captured 6 Mangrove Cuckoos (*Coccyzus minor*) at J.N. "Ding" Darling National Wildlife Refuge (Ding Darling) during 2012. Each was outfitted with a 2-gram radio transmitter, which we used to determine the bird's location for up to 4 months after its release. We found that Mangrove Cuckoos were present on Ding Darling throughout most of the year, although no single individual remained on Ding Darling for the entire year. Two individuals were present in spring but left at the onset of the wet season. Three individuals were present on Ding Darling from spring until mid-summer, but then left in July and August. One individual was captured in July and remained on Ding Darling until December. Mangrove Cuckoos appear to wander widely, and it is unclear whether individuals show fidelity to any particular area. Mangrove Cuckoos are quite vagile, with one individual making a 30-km round-trip journey to the mainland and back in a single day. Based on movement patterns and physical evidence in the form of a regressed brood patch on a captured individual, we suggest that the breeding season runs from approximately April to July. Two individuals that were present on Ding Darling during the putative breeding season occupied home ranges of 16.9 and 25.0 ha, respectively. These are far larger than would be predicted based on the body size of Mangrove Cuckoos and have important implications for conservation. Mangrove Cuckoos apparently require fairly large areas of intact mangrove – we found no evidence that they consistently use any other vegetation type – and will most often occur at low densities. Area sensitivity and low population density are both strongly correlated with extinction risk.

INTRODUCTION

Mangrove Cuckoos (*Coccyzus minor*) are a rare inhabitant of the mangrove forests and woodlands of southern Florida. A tropical species, they are found nowhere else in the United States. Within Florida's mangroves they have a wide distribution, but are present at relatively few locations and absent from many areas that appear habitable; where they are found, they occur at very low abundance (Lloyd and Slater 2012). Both the U. S. Fish and Wildlife Service and Partners in Flight identified Mangrove Cuckoos as a species at risk of becoming endangered, primarily because of its narrow range and specialized habitat requirements. Recent analyses of population trends lend credence to this concern: Mangrove Cuckoos declined by 85% between 2000 and 2008 in the Ten Thousand Islands NWR and adjacent lands in southwest Florida (Lloyd and Doyle 2011). The cause of this decline is unknown.

Diagnosing the ultimate causes of a population decline and developing an effective conservation strategy requires an understanding of the ecology and natural history of the species, information which is lacking for Mangrove Cuckoos. In 2012, Ecostudies Institute, with assistance from J.N. "Ding" Darling National Wildlife Refuge (Ding Darling), Ten Thousand Islands National Wildlife Refuge, and the Disney Wildlife Conservation Fund, initiated a radio-telemetry study of Mangrove Cuckoos with the goal of improving our understanding of the ecology and seasonal movements of Mangrove Cuckoos. Specific objectives included:

1) documenting seasonal movements of Mangrove Cuckoos using radio-telemetry;

2) documenting the annual phenology of Mangrove Cuckoos at Ding Darling using radio-telemetry and behavioral observations;

3) documenting daily movements of Mangrove Cuckoos at Ding Darling using radio-telemetry and estimate home range size.

This report summarizes all activities conducted during the performance period of the project.

FINDINGS

Task 1. Documenting seasonal movements of Mangrove Cuckoos.

Summary: In this section, we first discuss methods related to this task, and then provide results regarding the test of our telemetry system and our effort to document seasonal movements. We conclude that our telemetry system was adequate for documenting movements of Mangrove Cuckoos and delineating their home ranges. We also conclude that Mangrove Cuckoos do not reside year-round on a single home range, but appear to wander widely throughout the year. Some individuals are present on Ding Darling throughout the year, although we did not find that any single individual remained on Ding Darling year-round. Some individuals are present in early spring and leave prior to the onset of summer rains, other individuals remain on Ding Darling until mid-summer before leaving, and some individuals appear in late summer and remain at Ding Darling through the winter. The destination of individuals leaving in mid-summer is unclear, but may be as far as the Keys or beyond.

Methods

We conducted systematic call-playback surveys throughout Ding Darling from February - August. We conducted surveys on foot along the length of Wildlife Drive, Indigo Trail, Shell Mound Trail, Oak Hammock Trail, Dixie Beach Boulevard, Woodring Road, the unnamed trails that run north-south from the Sanibel-Captiva Road into Ding Darling, and the Lee County Electric Cooperative powerline right-of-way. We also conducted surveys by kayak in Tarpon Bay, Sanibel Bayou, and Hardworking Bayou. During the surveys, an observer broadcast an approximately 5-second recording of a Mangrove Cuckoo vocalization over a portable audio speaker. The observer would then listen silently for 30 seconds to 1 minute. Any response – whether it was an individual that was seen or heard – was noted, as was the approximate location of the responding individual.

We returned on subsequent days to areas where individuals had been detected and attempted to capture them. We erected mist-nets, typically along the edge between mangrove vegetation (defined generally as groups of individuals of *Rhizophora mangle*, *Laguncularia racemosa*, *Avicennia germinans*, or *Concarpus erectus*, either alone or in mixed-species associations) and open water or the trail or road, and attempted to lure individuals into the net via the use of a portable speaker that broadcast the same recorded vocalization used during surveys. Upon capture, individuals were banded with a single USFWS aluminum leg band and 3 plastic, colored leg bands. We then affixed a 2-gram radio transmitter to the rump of each bird using the thigh-harness method of Rappole and Tipton (1997). We constructed the harness out of flat, braided elastic (0.25 inch in width) purchased from a fabric store. This material proved durable and non-irritating (based on our inspection of 150.603, which was recaptured 2 months after it was initially fit with the harness), but will eventually fail and release the transmitter and harness from the bird. Individuals were released at the point of capture as soon as the harness and transmitter were securely attached. Upon release, most individuals flew to a nearby perch, preened their feathers over the transmitter, and then left the area. In no case did we ever observe an individual that appeared hindered or bothered by the harness or transmitter.

We tracked marked individuals on foot and from kayaks using a handheld 3-element Yagi antenna. Daily tracking began after the first individual was captured (13 April) and continued regularly until August. After August, tracking efforts were reduced to approximately 1 day of searching every 2-4 weeks. We focused initial search efforts for marked birds in the vicinity of the capture area, but broadened our search if we did not locate the signal. We conducted systematic searches along all of the roads and trails and throughout Tarpon Bay and Sanibel and Hardworking Bayous for individuals that could not be located. In July, when most of our marked individuals had apparently left the area, based on multiple surveys without any detection, we began conducting aerial searches from an airplane. Initial aerial searches focused on the area from the mouth of Charlotte Harbor to Estero Bay, but were subsequently broadened to include the coastline between Sanibel and Flamingo in Everglades National Park.

When tracking birds on foot or by boat, we used biangulation and triangulation to estimate the location of signals. During aerial searches, locations were determined by flying successively smaller circles around the signal until an approximate location was estimated using the plane's navigational Global Positioning System (GPS). All of the location data are estimates, and thus subject to both random and systematic sources of error, and so we conducted a test of the accuracy and precision of our telemetry system.

To test the telemetry system, a naïve observer used biangulation to identify the location of a radio transmitter that had been placed in a known location by a second observer. The transmitters were placed on horizontal limbs of mangrove trees in locations that appeared representative of areas used by Mangrove Cuckoos. We conducted 16 trials; 6 in February of 2012 and 10 in July of 2012. The same observer was used in every trial. In 14 trials, the observer was able to obtain bearings from land, but in the other 2 trials the location of the hidden transmitter required the observer to take bearings from a kayak. We calculated error as the distance between the actual location of the transmitter as determined by a handheld GPS unit and the location estimated from biangulation.

Telemetry error

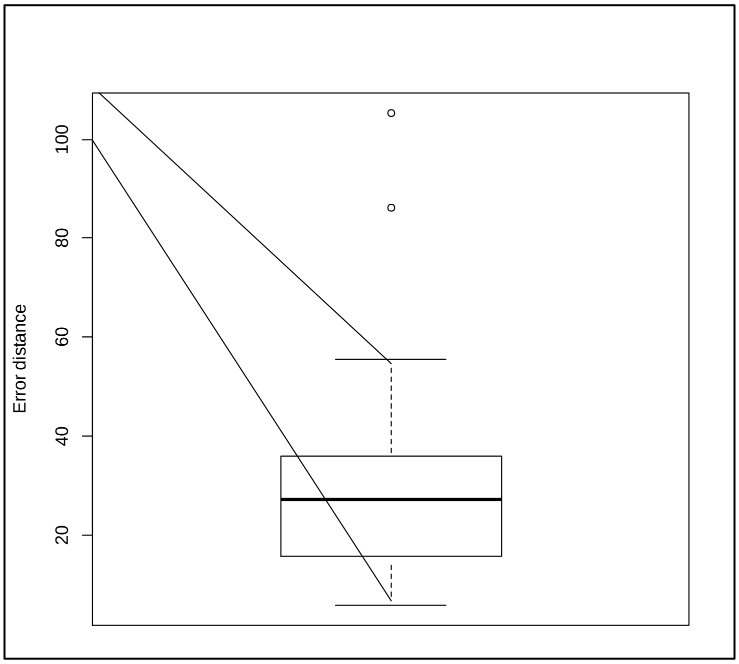

Figure 1. Boxplot of estimated error distances obtained during 16 tests of a radio-telemetry system in mangrove forest in southwest Florida.

The median error was 27.1 m and the interquartile range was 20.3 (first quartile: 15.6; third quartile: 35.9) (Fig. 1). The estimated mean error was slightly higher (35.1 m, SD = 28.6 m), reflecting the influence of 2 outlying values where estimated error was > 80 m (Fig. 1). Error distance was strongly and positively associated with distance between the signal and the receiver (b_{distance} = 0.3, t_{12} =5.3, P < 0.001) (Fig. 2). Every 1 m increase in the average distance between the two points used in biangulation and the location of the signal was predicted to produce a 0.3 m (95% CI = 0.16 – 0.40) increase in error distance.

Telemetry error may be random in nature, for example due to deflection of the radio waves by vegetation or open water or measurement error associated with using a handheld compass to determine the bearing to the signal (i.e., accurate alignment of the compass along the antenna is difficult, as is accurately aligning the compass needle with magnetic north). Consistent error, or bias, may arise if receivers are situated repeatedly in the same location and if signal bounce in these locations is consistent or if systematic measurement error occurs. Sources of systematic measurement error might include a misaligned compass or a tendency for the observer to consistently over- or underestimate the direction of the signal. Bearing errors in

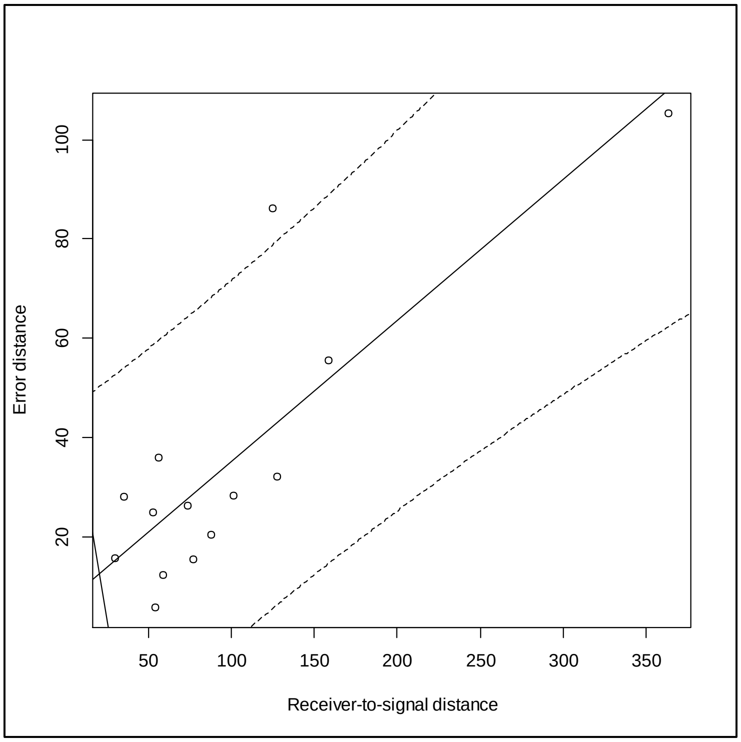

Figure 2. Predicted error distance (solid line; dashed lines show prediction intervals) increased as the distance between receivers and the signal increased (data shown as open circles).

our trials were approximately normally distributed, suggesting a random component to bearing error, but were located around a mean of -6.4°, suggesting small but consistent bias in our estimates of signal direction (Fig. 3).

The apparent error estimated from these trials is relatively low in relation to the likely home-range size of Mangrove Cuckoos. Using the formula in Moser and Garton (2007), the error ratio (the ratio of estimated precision expressed as an area to home-range area) from our telemetry trials is approximately 0.01; Moser and Garton (2007) found that home-range estimates were biased when the error ratio exceeded 0.01. As such, we feel confident that our telemetry system is adequate for documenting daily and seasonal movements of Mangrove Cuckoos and accurately estimating home ranges.

We also tested our ability to locate radio-tagged birds from a fixed-wing airplane. On 14 August, we conducted flights at different altitudes above a transmitter positioned at a known location in a mangrove forest. The plane passed directly over the transmitter at 305 m (1000 ft), 457 m (1500 ft), and 610 m (2000 ft) and then flew passes at different distances to either side of the transmitter, again repeating passes at each of the 3 altitudes. Flying directly over the transmitter at 305 m altitude, the signal was detected 1.08 km before the plane passed over the transmitter and was lost when the plane had passed 1.01 km beyond the location of the signal. At this altitude, the signal was not detected at the 1 or 2 km offset passes. At 457 m altitude, the signal was detected 1.81 km before the plane passed over the transmitter and was lost when the plane had passed 800 m beyond the transmitter. The signal was located on offset passes as far as 2 km adjacent to the path directly over the signal. At 610 m altitude, the signal was detected 1.74 km before the plane passed over the transmitter and was lost when the plane had passed 900 m beyond the transmitter. The signal was located on offset passes as far as 2 km adjacent to the path directly over the signal. These results suggest that signal reception was better at flight altitudes of 300 – 450 m and that at these altitudes the detection radius for a transmitter on the ground was approximately 1-2 km.

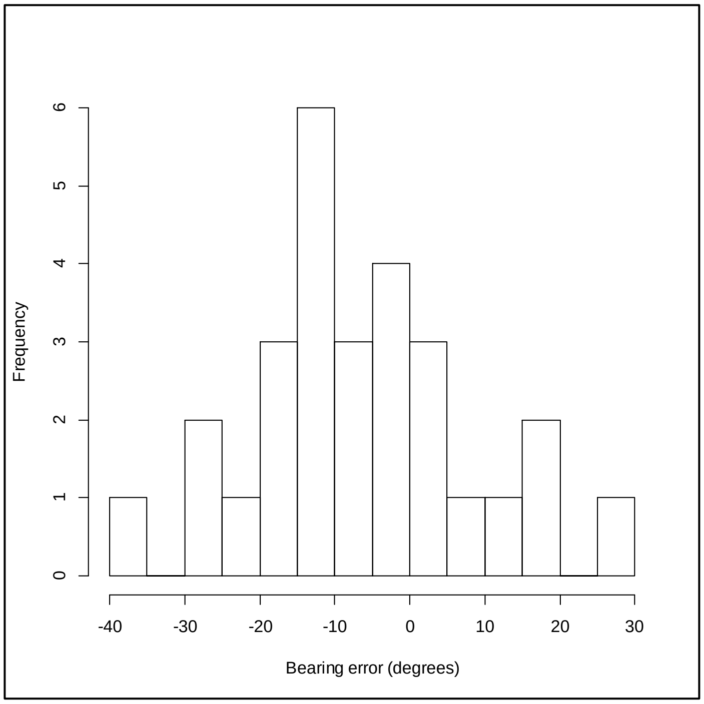

Figure 3. Distribution of bearing error (degrees between estimated bearing and true bearing) obtained during 16 trials of a radio-telemetry system in mangrove forest of southwest Florida.

Seasonal movements

We captured and marked 6 individuals (Table 1). One individual was only re-located once, on the day after its initial capture. The other five were followed for at least 3 weeks (Table 1). All of the individuals that we tracked moved large distances over the course of the study, and none were present at Ding Darling continuously. It appears that individuals use Ding Darling during both the breeding and non-breeding season, but none of the birds that we followed were present during both seasons. For example, the first capture, 150.603 (identification numbers for each bird refer to the frequency of the signal emitted by the radio transmitter they carry), was consistently found south of Wildlife Drive between the powerline and Cross Dike from 13 April until 12 May, at which point it apparently left Ding Darling. This bird was relocated on 19 July in Charlotte Harbor Preserve State Park near Matlacha Pass, and was present there until our last survey on 14 August (Fig. 4). Based on this sequence of events, one possibility is that the bird stopped over at Ding Darling for the winter or during migration to the breeding ground, and then left to establish a territory near Matlacha Pass.

Table 1. Summary of capture and tracking data for 6 Mangrove Cuckoos trapped at J.N. “Ding” Darling National Wildlife Refuge in 2012, affixed with radio transmitters, and tracked until December 2012.

Frequency	Capture date	Capture location	Final location	Date of final location	Status	Total number of locations	Days followed
150.603	4/13/2012	Powerline right-of-way, south of Wildlife Drive (0385485 E, 2928435 N)	Charlotte Harbor Preserve State Park, southeast of Matlacha Pass (0395249 E, 2939372 N)	8/14/2012	Unknown.	49	123
150.613	4/28/2012	Powerline right-of-way, south of Wildlfie Drive (0385495 E, 2928384 N)	Hardworking Bayou, J.N. “Ding” Darling NWR (0387004 E, 2928392 N; approximate)	6/18/2012	Transmitter removed.	35	51
150.621	5/7/2012	Cross Dike (0386921 E, 2927195 N)	Matlacha Pass NWR (0395249 E, 2939372 N)	7/20/2012	Unknown.	50	74
150.630	5/18/2012	Wildlife Drive, approximately Mile Marker 3 (0387459 E, 2927062 N)	Hardworking Bayou, J.N. “Ding” Darling NWR (0387014 E, 2827865 N)	5/20/2012	Presumed left study area.	2	2
150.811	6/29/2012	Wildlife Drive at powerline right-of-way (0385427 E, 2928786 N)	Sanibel Bayou, J.N. “Ding” Darling NWR (0389675 E, 2926856 N)	7/23/2012	Unknown.	14	24
150.919	7/8/2012	Wildlife Drive, approximately 0.1 mile beyond fee booth (0389007 E, 2925937 N)	Sanibel Bayou, J.N. “Ding” Darling NWR (0388600 E, 2925939 N)	11/21/2012	On Refuge through 21 November 2012.	28	136

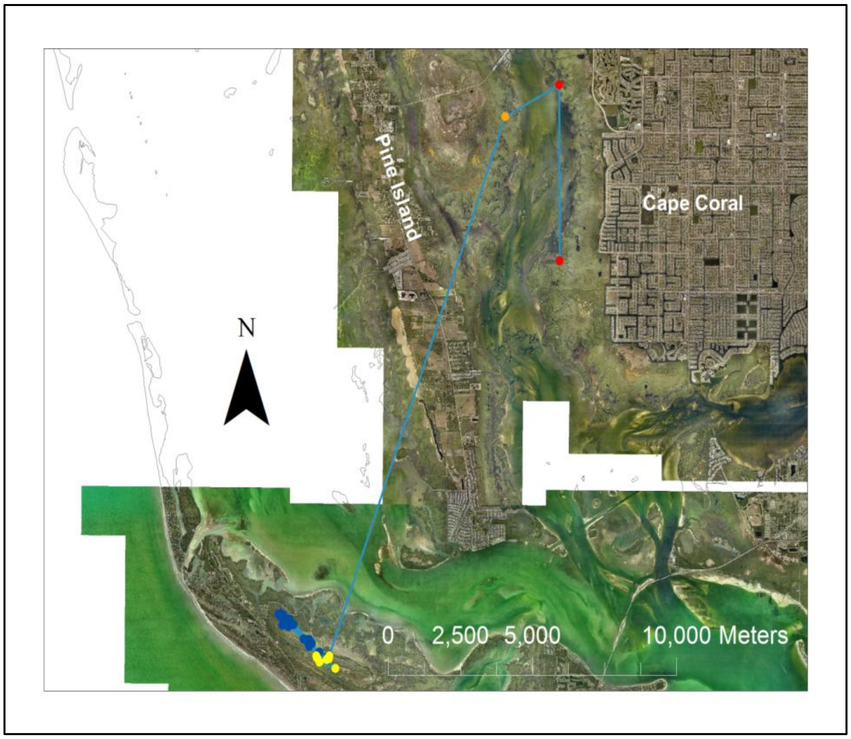

Figure 4. Locations (colored circles) and inferred movements (solid blue line) of a Mangrove Cuckoo (150.603) captured 13 April 2012 at J.N. "Ding" Darling National Wildlife Refuge and fitted with a radio-transmitter. This individual spent most of April (blue dots) and May (yellow dots) on the Refuge, before disappearing sometime after 12 May 2012. The bird was later relocated on 19 July (orange dot) near Matlacha Pass during an aerial search, and was found in the same vicinity in the Charlotte Harbor Preserve State Park at two searches in August (red dots).

In contrast, two individuals (150.613 and 150.621) captured in late April and early May remained in the area for approximately 2 months. One of them, 150.621, then relocated in July to an area just north of Matlacha Pass, approximately 4 km from the area where 150.603 was detected in July and August (Fig. 5). 150.621 was not relocated after July. We are reasonably certain that it did not return to Ding Darling, as search efforts were intensive until mid-August, but whether it remained undetected somewhere in the Cape Coral/Pine Island area or wandered outside of the search area is unclear.

150.613 spent May and June in a well-defined area in Hardworking Bayou north of Cross Dike (Fig. 6). This individual was captured along the power line right-of-way (Fig. 6) in nearly the same location as 150.603, but was next found in the area that it appeared to occupy until mid-June, at which point we recaptured and removed the harness after the bird became entangled on a branch. We have no information on this bird's movements after its second release.

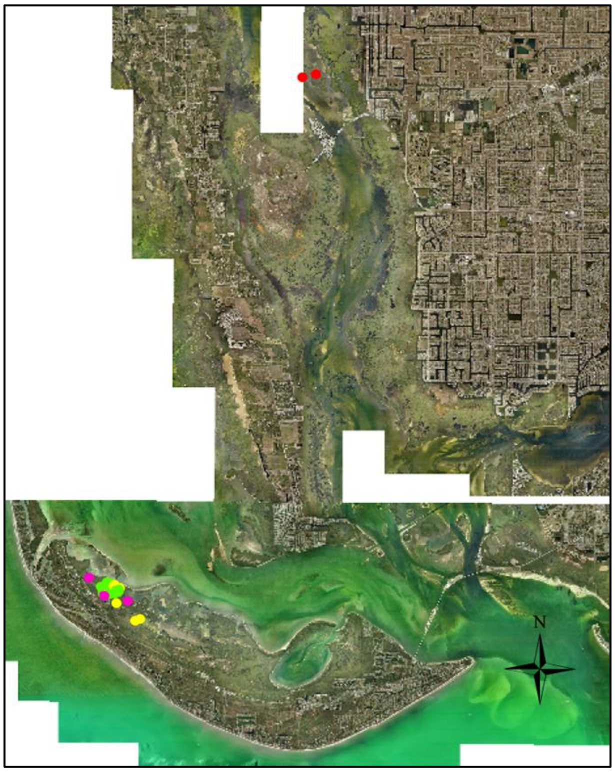

Figure 5. Estimated locations of 150.621 during May, June, and early July (yellow, green, and pink dots, respectively), when the bird was present on Ding Darling, and late July (red dots), after the bird had relocated to the Matlacha Pass area. The late July locations are approximately 25 km from the cluster of points on Ding Darling.

150.811 was not captured until late June and was only followed for 24 days, but during this time was closely associated with 150.621 and appeared to share its home range (Fig. 7). Indeed, we suspect that 150.811 was associating with 150.621 long before we captured it, as we saw 150.621 in the company of a second bird as early as 11 May. 150.811 gradually moved east towards Tarpon Bay after 150.621 left the area, and finally disappeared from Ding Darling, never to be relocated, on 23 July.

The last individual that we captured, 150.919, was not captured until July, but it remained in the same area on Ding Darling until late November (Fig. 8). This bird showed evidence of a regressed brood patch, suggesting it may have been a wandering, post-breeding individual (Fig. 9). Its capture location was not far from an area along the Commodore Creek Trail where a pair of birds was suspected to have nested, and so it may have been a bird that nested locally. Aside from a one-day journey to Bunche Beach Preserve (on 19 July it was located during an aerial search; it was detected during ground tracking on Ding Darling on both 18 and 20 July), 150.919 was always located in the area between Wildlife Drive and Tarpon Bay.

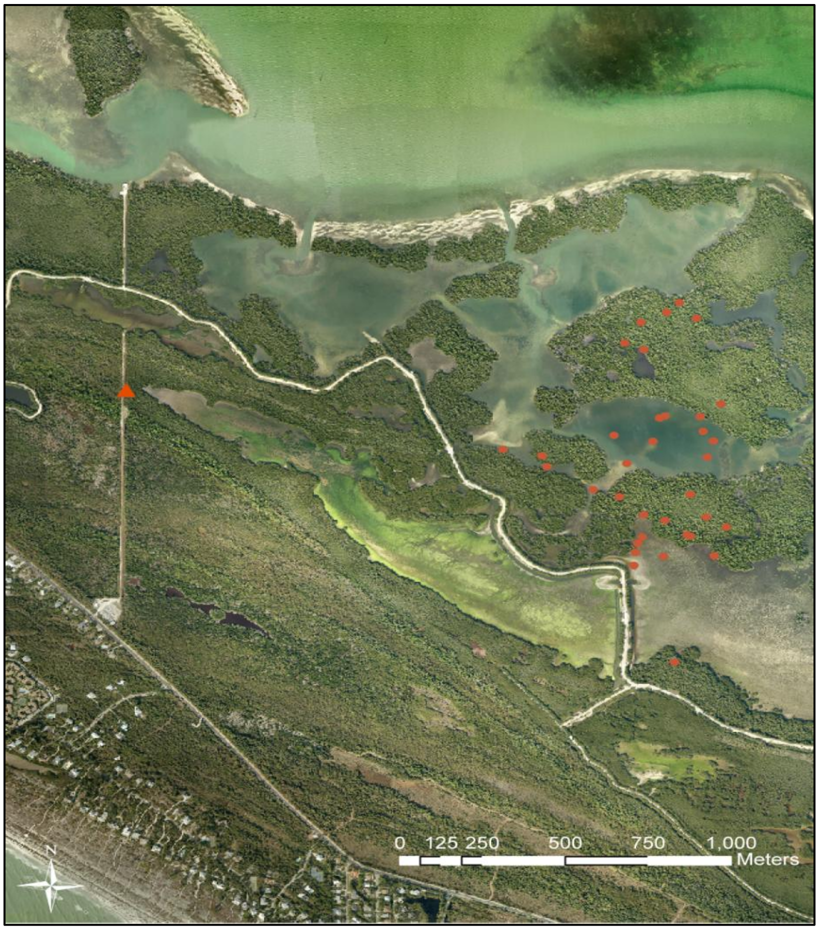

Figure 6. Capture location (orange triangle) and subsequent estimated locations (orange circles) of 150.613 during May and June at Ding Darling. We removed the transmitter from 150.613 in June, and so no further locations could be obtained. Points located over open water reflect telemetry error.

These data suggest that Mangrove Cuckoos wander widely and that they use Ding Darling both during and outside of the breeding season. The individuals that we followed did not remain on a single, discrete home range throughout the year. Some individuals (e.g., 150.603 and 150.630) were present on Ding Darling only in early spring, apparently leaving at the onset of the wet season to occupy areas outside of Ding Darling. Other individuals remained on Ding Darling through mid-summer, only to relocate to other areas in July and August. Finally, one individual (150.919) remained on Ding Darling through at least early winter, and so Mangrove Cuckoos, at least in this part of their range, are not strictly migratory. However, the disappearance of 150.621, which carried a transmitter with approximately 2 months of battery life remaining at

Figure 7. Capture location (yellow triangle) and subsequent estimated locations (yellow circles) of 150.811 during June and July at Ding Darling. 150.811 occupied the area reflected by the cluster of points on the west side of Ding Darling, but left that area and apparently wandered east after 150.621, with which 150.811 was associating, left Ding Darling for Matlacha Pass. The four points on the east side of Ding Darling were the last four detections of 150.811 before it disappeared.

its last detection, and 150.811, which disappeared in July but had a transmitter expected to function until November, raise questions about how far individuals, even if they are not truly migratory, may move during the year. We conducted aerial searches over most of the coastal mangroves (that is, the area of nearly continuous mangrove vegetation bordered by freshwater marsh on the interior side and by Florida Bay and the Gulf of Mexico on the downstream side) from Charlotte Harbor to Flamingo, yet detected no marked birds. We see three possible explanations.

First, it is possible that we failed to detect marked birds that were present, although we established our flight lines using the results of our test of the telemetry system, so we are confident that we had nearly complete coverage of the coastal mangroves. It is also possible

Figure 8. Capture location (aqua triangle) and subsequent estimated locations (aqua circles) of 150.919 during July - November at Ding Darling. Not shown is a single location at Bunche Beach Preserve, where 150.919 spent the day on 19 July. It was located on Ding Darling on both 18 July and 20 July.

that our marked birds moved further south or east, perhaps into the Florida Keys or beyond. Finally, 150.621 and 150.811 may have moved outside of search area by travelling north or by moving inland to occupy areas outside of the mangroves. However, given the lack of extensive mangrove vegetation north of Charlotte Harbor, and that Mangrove Cuckoos rarely use habitats other than mangrove or hardwood hammock, we feel this is less likely than either of the other two explanations.

In sum, Mangrove Cuckoos are present on Ding Darling throughout the year, although we did not find that any single individual remained on Ding Darling year-round. Some individuals that were present in early spring left prior to the onset of summer rains, whereas other individuals remained on Ding Darling until mid-summer before leaving. Finally, some individuals apparently appear in late summer and remain at Ding Darling through the winter. The destination of individuals leaving in mid-summer is unclear but, given the failure of our aerial search to yield any detections, may be as far as the Keys or beyond.

Figure 9. The last Mangrove Cuckoo captured at J.N. "Ding" Darling National Wildlife Refuge in July 2012, 150.919, had an old brood patch that was in the process of regressing and refeathering. The presence of the brood patch suggests that this bird had been incubating recently.

Task 2. Documenting the annual phenology of Mangrove Cuckoos.

Summary: In this section, we discuss observations that shed some light on the phenology of Mangrove Cuckoos, in particular the onset and duration of breeding. Our approach is largely qualitative, relying on our interpretation of the data collected for Task 1. Based on movement patterns and physical characteristics of captured birds, we conclude that breeding may commence as the dry-season ends, perhaps in April or May, and continues until at least July. We note, however, that other New World cuckoos show remarkably labile and often very extended breeding seasons – in some cases, year-round – and suggest that additional observations may yield a very different view of breeding phenology.

We did not obtain any direct evidence of breeding among Mangrove Cuckoos, but we suspect that both 150.613 and 150.621 attempted to breed on Ding Darling. Both birds were frequently seen in the company of a second individual (in the case of 150.621, the accompanying bird was also radio-tagged [150.811]) and both radio-tagged birds showed consistent use of a home range during the period when other birds of the mangroves are known to breed. Based on purely circumstantial evidence, we infer that the breeding season begins in May and ends in July. Our first capture, 150.603, was consistently found south of Wildlife Drive between the powerline and Cross Dike from 13 April until 12 May, at which point it apparently left Ding Darling. This bird was relocated on 19 July in Charlotte Harbor Preserve State Park near Matlacha Pass, and was present there until at least 14 August (Fig. 4). Based on this sequence of events, one possibility is that the bird stopped over at Ding Darling for the winter or during migration to the breeding ground, and then left to establish a territory near Matlacha Pass. This would suggest that the breeding season begins sometime in the early wet season, perhaps late April or early May. Similarly, 150.630, which was captured 18 May, was only relocated once, on 20 May. Like 150.603, this bird may have been captured just as it was preparing to depart for its breeding territory. The two marked individuals that we believe constituted a pair, 150.621 and 150.811, were together consistently from May until July (although 150.811 was not captured until June, a bird that we suspect was 150.811 was frequently observed with 150.621 prior to that), at which

Figure 10. The first Mangrove Cuckoo captured in April 2012 at J.N. "Ding" Darling National Wildlife Refuge, 150.603, had a scaly abdomen with one feather regrowing. This may have been due to adventitious feather loss, or it may be the final stages of a regressing brood patch.

point they ceased associating with one another and eventually left Ding Darling. Around the same time, 150.919 was captured and showed evidence of recent breeding in the form of a regressing brood patch (Fig. 9). This would further support the notion of a breeding season that comes to an end in July. A breeding season incorporating the early to middle wet season would be consistent with the strategy employed by other species in the mangroves, but we note that our conclusions are speculative and require empirical support in the form of direct observations of breeding. Interestingly, our first capture on 13 April, 150.603, appeared to have a bare, scaly abdomen with at least one new body feather emerging from its shaft (Fig. 10). We are uncertain whether this was an old brood patch or simply the result of adventitious feather loss, but if was an old brood patch then it would indicate breeding well outside of the time frame we propose here. Yellow-billed Cuckoos (*C. americanus*) breeding in temperate North America have highly flexible breeding seasons, apparently a trait that allows them to take advantage of unpredictable outbreaks of insects (Nolan and Thompson 1975), and at least one tropical cuckoo (*C. pumilus*) breeds year-round when food is sufficient (Ralph 1975).

Task 3. Documenting daily movements and estimating home-range size of Mangrove Cuckoos.

Summary: In this section, we first discuss methods related to this task, and then provide results regarding home-range size in Mangrove Cuckoos at Ding Darling. For the two individuals with a sufficient number of locations, we estimated home-range size at 17 and 25 ha, respectively.

Methods

Location information for each individual was gathered using the methods described under Task 1. We used adaptive local convex hulls (Getz et al. 2007) to create an initial estimate of the location and size of home ranges for 2 individuals, 150.613 and 150.621. We had a relatively large number of estimated locations for both and each used a fairly discrete area on Ding Darling for approximately 2 months, suggesting that they were residents and not wandering individuals. The time period that these two individuals were resident coincides with the putative breeding season that we have defined under Task 2, so we have tentatively defined the home ranges we identify as breeding-season home ranges.

We used the heuristics provided by Getz et al. (2007) to parameterize the estimator and calculated the 90% isopleth for the resulting utilization distribution (i.e., the utilization distribution that contained 90% of the locations for each individual). We used the 90% isopleth rather than the more conventional 95% isopleth based on the findings of Borger et al. (2006) that 90% isopleths were less biased. Within a Geographic Information System (GIS), we overlaid the estimated home range for each individual on a spatially referenced aerial image of Ding Darling and clipped any part of the home range that included open water. Error introduced by using biangulation and triangulation resulted in numerous estimated locations that were in open water, which in turn influenced the boundaries of the estimated home range. In addition, we also made subjective adjustments to the boundaries estimated for 150.621, as we felt that the estimated boundaries were in some cases artificial. In particular, 150.621 used a very discrete patch of forest bounded by Wildlife Drive, a housing subdivision, and Pine Island Sound. The 90% isopleth included most, but not all, of this patch, but there was no obvious biological reason to exclude the areas outside of the 90% isopleth yet within the patch of forest. Instead of reflecting some underlying biological reality, we suspect that the boundaries of the estimated home range reflected the small number of locations available for 150.621. Indeed, boundary shape should be strongly influenced by sample size, with accurate edges appearing only at large sample sizes. Adjusting the boundaries to coincide with the shape of the forest patch increased the estimated home-range size by approximately 20%.

Daily movements

We gathered 176 estimated locations for the 6 marked individuals, with 2-50 locations for each individual (Table 1). As a group, these individuals were found throughout the mangroves of Ding Darling (Fig. 11). We did not detect Mangrove Cuckoos using hardwood hammocks or the complex of buttonwood woodland and *Spartina*/*Cladium* marshes that occur between the Sanibel-Captiva Road and the inland edge of the mangroves. Mangrove Cuckoos did not show any obvious avoidance of artifical edges, although in the case of 150.621 they appeared to define the boundaries of the home range: a housing subdivision on one side, and Wildlife Drive on another (Fig. 11). Other notable detections include 150.811 using mangroves adjacent to the Sancturary Golf Club and 150.919 frequenting the area around the entrance gate, Indigo Trail, and even the Sanibel School on one occasion (Fig. 11). 150.919 also made a remarkable one-day trip from the area it occupied most of the summer and fall, near the entrance gate on Wildlife Drive, to Bunche Beach Preserve, a straight-line distance of nearly 30 km. This individual was located along Wildlife Drive on 18 July, was found in Bunche Beach Preserve during an aerial survey om 19 July, and was found again along Wildlife Drive on 20 July.

Home-range location and size

The home range for 150.613 was estimated at 16.9 ha (Fig. 12). The home range for 150.621, after our modification of the boundary, was 25.0 ha (Fig. 12); the estimate from the 90% isopleth was 20.4 ha. The size of the estimated home ranges was noteworthy, far exceeding the values predicted based on body size, which is closely linked to home-range size in birds (Schoener 1968, Baker and Mewaldt 1979). Indeed, allometric relationships predict a home range size of approximately 10 ha for a bird with a body mass equal to that of Mangrove Cuckoo (approximately 65 g). The home-range sizes we estimated for the two individuals in this study

Figure 11. Locations of 6 Mangrove Cuckoos as estimated by radio-telemetry. Circles of different colors reflect different individuals (yellow: 150.603; orange: 150.613; green: 150.621; purple: 150.630; blue: 150.811; pink: 150.919); triangles show capture location for each bird. 150.613, 150.621, and 150.811 were present May-July; 150.603 was present April-May; 150.919 was present July-December; and 150.630 was present on two days in May.

were similar to those seen in small hawks and owls (Schoener 1968). Similarly large home ranges have been reported for other cuckoos, including Yellow-billed Cuckoo (*Coccyzus americanus*) (Haltermann 2009) and Guira Cuckoo (*Guira guira*) (Souza 1995). The pattern we have begun to describe here, should it prove consistent as our sample size increases, may have significant implications for conservation. First, it suggests that Mangrove Cuckoos require large areas of mangrove forest and that they are apt to exist at relatively low densities. Low population density and a requirement for large areas of habitat are apt to make Mangrove Cuckoos sensitive to disturbance and prone to local extinctions. Furthermore, their unusually large home ranges suggests that they have difficulty obtaining adequate amounts of food (see Nolan and Thompson 1975), which would make them especially sensitive to any changes in prey abundance (e.g., as might result from application of insecticides). Perhaps somewhat mitigating these concerns is the apparent willingness of Mangrove Cuckoos to use mangroves that are adjacent to developed areas, although without demographic data we cannot rule out the possibility that reproductive and survival rates are lower near artificial edges, as is seen in many other systems.

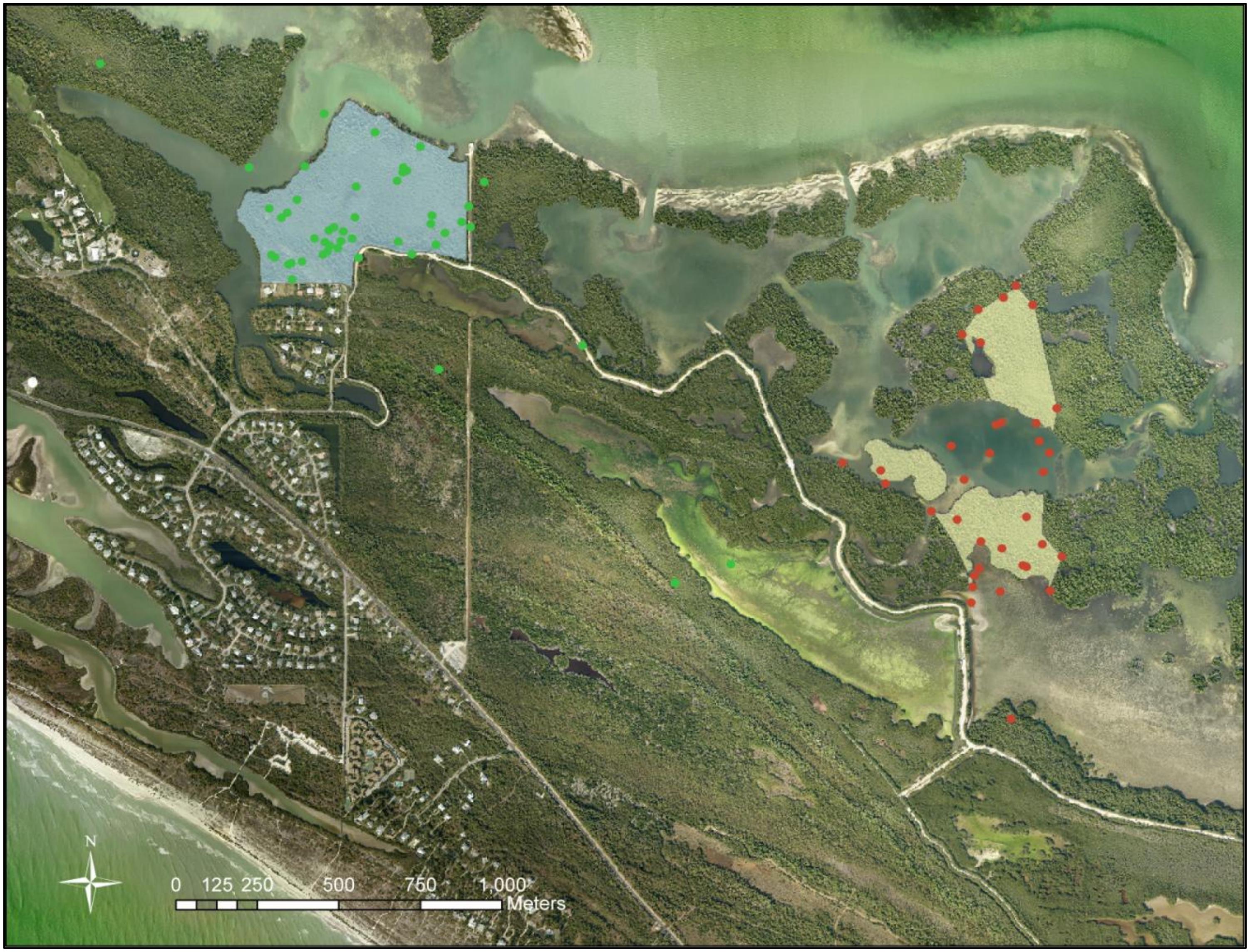

Figure 12. Estimated home ranges for two Mangrove Cuckoos at Ding Darling (150.621: blue polygon; 150.613: yellow polygon). Colored circles show locations of these two individuals as estimated using radio-telemetry. Home ranges were constructed based on the 90% isopleth from an analysis using adaptive local convex hulls.

CONSERVATION AND MANAGEMENT IMPLICATIONS

The most significant finding of our work to date is that Mangrove Cuckoos utilize large home ranges during what we believe is the breeding season. This suggests that they may require relatively large areas (e.g., at least approximately 20 ha) of mangrove forest when nesting. They do not appear to avoid artificial edges – for example, the home range of 150.621 was bounded by a housing development and a road – although we do not know whether edge effects on reproductive success occur. If reproductive success tends to be lower near artificial edges, then much of the available habitat north of Ten Thousand Islands is likely to be of relatively low quality because nearly all of the mangroves in this region abut residential developments or roads directly.

If the home ranges and patterns of habitat use that we have described in this study are characteristic of Mangrove Cuckoos in general, then Ding Darling can probably support no more than 10 pairs during the breeding season. We have no evidence that Mangrove Cuckoos use the hydrologically altered mangrove forests on the impounded side of Wildlife Drive during the breeding season, although marked birds did use these areas during the winter. Thus, the only apparently suitable areas for breeding birds on Ding Darling are the taller mixed-mangrove forests of the bayous and around Tarpon Bay. Conservation efforts should thus be targeted broadly to ensure that all large stands of mangrove vegetation in the area remain intact, as the local population of birds on Ding Darling is clearly too small to remain viable as an independent unit. The connectivity of mangrove vegetation in the region is clearly illustrated by the movement of marked birds between Ding Darling and Charlotte Harbor Preserve State Park, Matlacha Pass National Wildlife Refuge, and Bunche Bay Preserve. Given patterns of land ownership, conservation of Mangrove Cuckoos in the region will require collaboration between county, state, and Federal agencies.

RESEARCH NEEDS

Our findings are based on a small sample of birds, so gathering information on daily and seasonal movements of additional birds must be a priority. Verifying our assumptions about breeding-season phenology by documenting nesting should also be a main priority, as should data collection that allows estimation of reproductive success and the factors that influence it. Finally, significant gaps remain in our understanding of seasonal movements, and we suggest that extensive aerial searching during the fall and winter, especially of the Florida Keys, might yield valuable information about the seasonal movements of Mangrove Cuckoos.

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