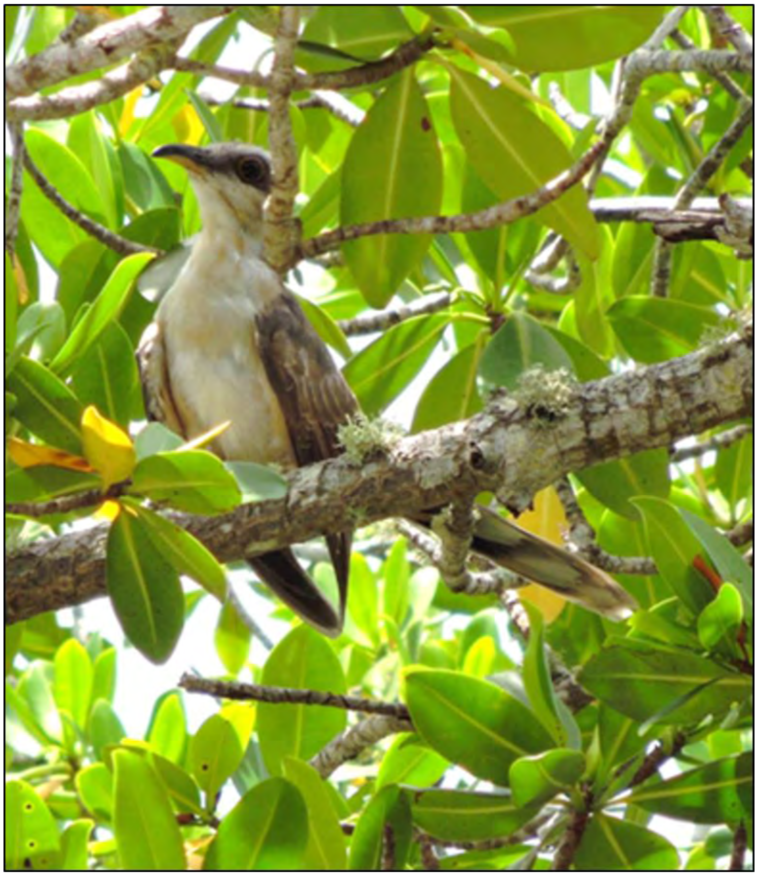

ANNUAL REPORT:

ECOLOGY AND SEASONAL MOVEMENTS OF MANGROVE CUCKOOS

COOPERATIVE AGREEMENT:	401818J604
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PERIOD COVERED:	1 January 2013 – 31 December 2013
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CONTENTS

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SUMMARY

We captured 10 Mangrove Cuckoos (*Coccyzus minor*) during 2013. Each was outfitted with a 2-gram radio transmitter, which we used to determine the bird's location for up to 6 months after its release. We found that Mangrove Cuckoos were present on J.N. "Ding" Darling National Wildlife Refuge throughout most of the year, with radio-marked birds known to be present on the refuge from March – September. In addition, we observed at least 3 different individuals on the refuge in December 2013, and several others on and near the refuge during February 2013, although none were banded. The only month of the year for which we currently lack observations is January, but that is largely due to the lack of survey efforts during that month. At least some individuals are present on the refuge throughout the year, but we have no evidence that any single individual is resident for the entire year.

As in 2012, radio-marked individuals appeared to use the refuge in different ways. The refuge appears to support both breeding and wintering birds. Three marked individuals were present during the late dry season (March – May) and left at the onset of the wet season (approximate dates of departure: 10 May, 14 May, and 7 June) to establish new home ranges at Shell Point, near Matlacha Pass, and along Charlotte Harbor, respectively. Several individuals remained on the refuge for the entire time that they were tracked, from the late dry season through August and early September. One individual was present on the refuge from May until early August, but then left Sanibel Island and wandered north to Matlacha Pass.

Estimated home-range sizes varied widely among individuals and among methods used to estimate the home-range boundaries, although all estimates suggest Mangrove Cuckoos use large home ranges. Estimated core-use areas ranged from 6.7 ha to 215.5 ha when using local convex hulls to estimate home range, and from 21.2 ha to 667.1 ha when we used kernel density estimates instead. We suspect that much of the observed variation in home-range sizes is due to lumping locations that were associated with different activities in the annual cycle of the birds. In other words, some of the estimated home ranges probably combine a breeding-season home range, which may be more closely circumscribed because adults are limited in how far they can wander from a nest, with pre- or post-breeding wandering and perhaps even a non-breeding home range. Improving the accuracy and precision of our home-range estimates will require more information on the activity of marked birds during the time that they are tracked.

We obtained first evidence of local breeding in the form of a family group that included two adults and two recently fledged juveniles. The appearance of the juveniles suggested that egg-laying had begun in late May or early June, which corresponds with our observations that some birds relocate to new areas – presumably breeding home ranges – in the middle of May.

Mangrove Cuckoos apparently require fairly large areas of intact mangrove – we found no evidence that they consistently use any other vegetation type – but showed no aversion to using habitat adjacent to developed land. Almost all of the locations where we detected Mangrove Cuckoos were on public or otherwise conserved land, highlighting the importance of land protection for the conservation of this species

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), the Ding Darling Wildlife Society, 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 our effort to document seasonal movements. In previous reports, we have shown that our telemetry system was adequate for documenting movements of Mangrove Cuckoos and delineating their home ranges. We conclude that most Mangrove Cuckoos occupy what is likely a breeding home range from approximately May – August, and that some may be resident in the same area for even longer. However, many individuals appear to occupy different areas before, during, and after the putative breeding season. Some individuals are present on Ding Darling throughout the year, but it is unclear whether any single individual occupies the refuge 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.

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. Outside of the refuge, we conducted surveys along John Morris Road, which bisects the San Carlos Bay – Bunche Beach Preserve. 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.

When an individual was detected, 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. Capture efforts were often conducted immediately after the initial detection, as we have found in previous years that individuals are rarely present in the same area on subsequent days. 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 (we have recaptured 2 individuals 1-2 months after their initial capture, and neither showed any evidence of damage from the harness), but will eventually fail and release the transmitter and harness from the bird. We have yet to recapture any individuals >2 months after their initial capture, so we do not yet know the approximate lifespan on the harness material, although we suspect that it is likely between 6 months and 1 year. 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. One individual that was captured on a relatively cold (< 60° F) morning required re-warming inside the cab of a truck before release, highlighting the sensitivity of this species to cool temperatures.

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 (15 March) and continued regularly until 22 August. After 22 August, interns from the Ding Darling biology program conducted weekly tracking efforts until 27 September. 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. We also conducted aerial searches from an airplane beginning in May, when some of our marked birds began dispersing. Initial aerial searches focused on the area from the mouth of Charlotte Harbor to Estero Bay, but in the fall we broadened our search to include the coastline between Sanibel Island 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.

Seasonal movements

We captured and marked 10 individuals in 2013 (Table 1), four more than in 2012. 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, some birds were present on the refuge during the dry season, but then moved to establish new home ranges – perhaps for breeding – in May and early June (Figs. 1-3). Others stayed in one location through the late dry season and well into the wet season (Figs. 4-6); 150.883 was present in the same area of the refuge from March until at least early September. Finally, one individual (Fig. 7) was present on the refuge during the wet season, but left in August and began wandering north to Matlacha Pass, where it remained for several weeks before its signal was lost.

We were unable to locate any radio-marked birds after September 26, despite 3 birds carrying transmitters that we expected to function until early to mid-November. 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 none of the missing birds. We see three possible explanations. First, it is possible that we failed to detect marked birds that were present during the aerial searches, although given that we conducted extensive ground searches at the same time, which are less likely to have overlooked marked birds that were present, the missing birds must still have moved well outside of the areas that were used earlier in the year. Second, it is possible that our marked birds moved outside of our search area, perhaps into the Florida Keys or beyond. Finally, the transmitter batteries may simply have failed earlier than expected.

In sum, we have no evidence that Mangrove Cuckoos occupy the same home range throughout the year, although one individual occupied an area of the refuge for nearly 6 months. Some individuals clearly occupy distinct home ranges at different times of year. Mangrove Cuckoos were present in and around Ding Darling throughout the year, although we did not find that any single individual remained in any one location, including on Ding Darling, year-round. We did not recapture or resight any of the 6 individuals captured in 2012, which hints at the possibility that Mangrove Cuckoos show relatively little site fidelity. 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. Seasonal movements are likely linked with the timing of breeding, which appears to begin in May and end perhaps as late as August. A puzzling observation in light of the extensive movements that we documented was responsiveness of individuals to playbacks of vocalizations throughout the year. Individuals responded aggressively to playbacks in from early February until mid-December, which is suggestive of a territorial response. In many cases, we observed what appeared to be pairs responding together to the playback. The presence of what appeared to be territorial pairs of birds outside of the putative breeding season is difficult to reconcile with the apparent pattern of low site fidelity and widespread wandering.

Table 1. Summary of capture and tracking data for Mangrove Cuckoos trapped at J.N. “Ding” Darling National Wildlife Refuge in 2013.

Frequency	Capture date	Capture location	Final location	Date of final location	Status	Total number of locations estimated
150.874	3/15/2013	Wildlife Drive between the entrance gate and water-control structure 1.	Sanibel Bayou, Ding Darling	7/15/2013	Inactive	75
150.883	3/16/2013	Wildlife Drive between mile 3 and the LCEC power line.	LCEC power line	8/22/2013	Inactive	90
150.765	4/19/2013	Wildlife Drive at Cross Dike.	Charlotte Harbor Preserve SP, Matlacha Pass area	8/8/2013	Inactive	26
150.928	4/26/2013	Wildlife Drive west of the LCEC power line.	Charlotte Harbor Preserve SP, Pt Charlotte area	8/22/2013	Inactive	29
150.757	5/9/2013	Commodore Creek Trail	Charlotte Harbor Preserver SP, Little Pine Island	8/22/2013	Inactive	26
150.775	5/14/2013	John Morris Road, Fort Myers	San Carlos Bay – Bunche Beach Preserve	9/9/2013	Inactive	69
150.865	5/20/2013	Dixie Beach Blvd	Dixie Beach Blvd	9/6/2013	Inactive	57
150.613	5/21/2013	Sanibel Bayou	San Carlos Bay – Bunche Beach Preserve	9/13/2013	Inactive	62
150.819	6/18/2013	John Morris Road, Fort Myers	San Carlos Bay – Bunche Beach Preserve	9/4/2013	Inactive	41
150.829	7/9/2013	John Morris Road, Fort Myers	San Carlos Bay – Bunche Beach Preserve	9/21/2013	Active	35

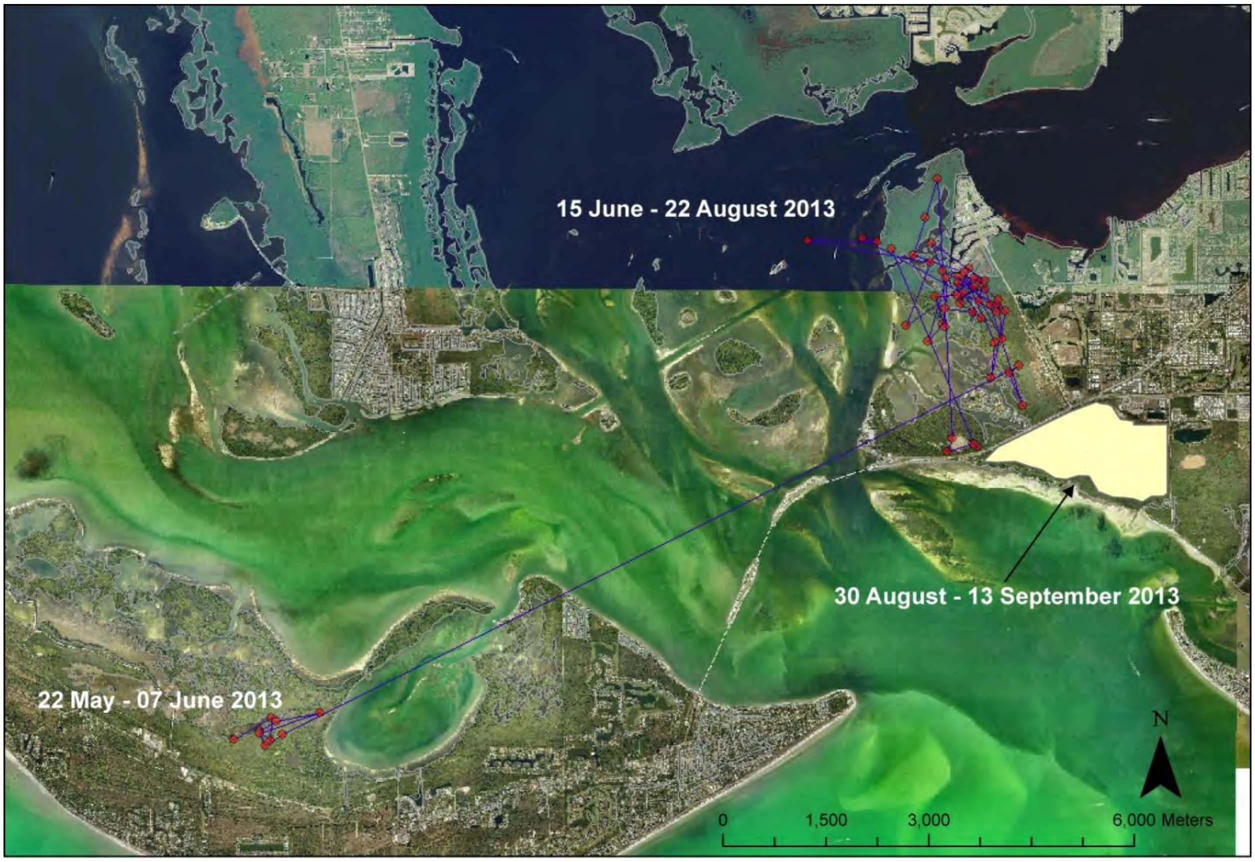

Figure 1. Individual 150.613 (2013) was captured on Sanibel Island on 21 May 2013, remained on the island until at least 07 June, and was relocated on 15 June in the vicinity of Shell Point. It remained in that area until at least 22 August. It was present in the area of the yellow polygon until 13 September, after which time it was not detected (including during aerial surveys on 21 and 22 September 2013).

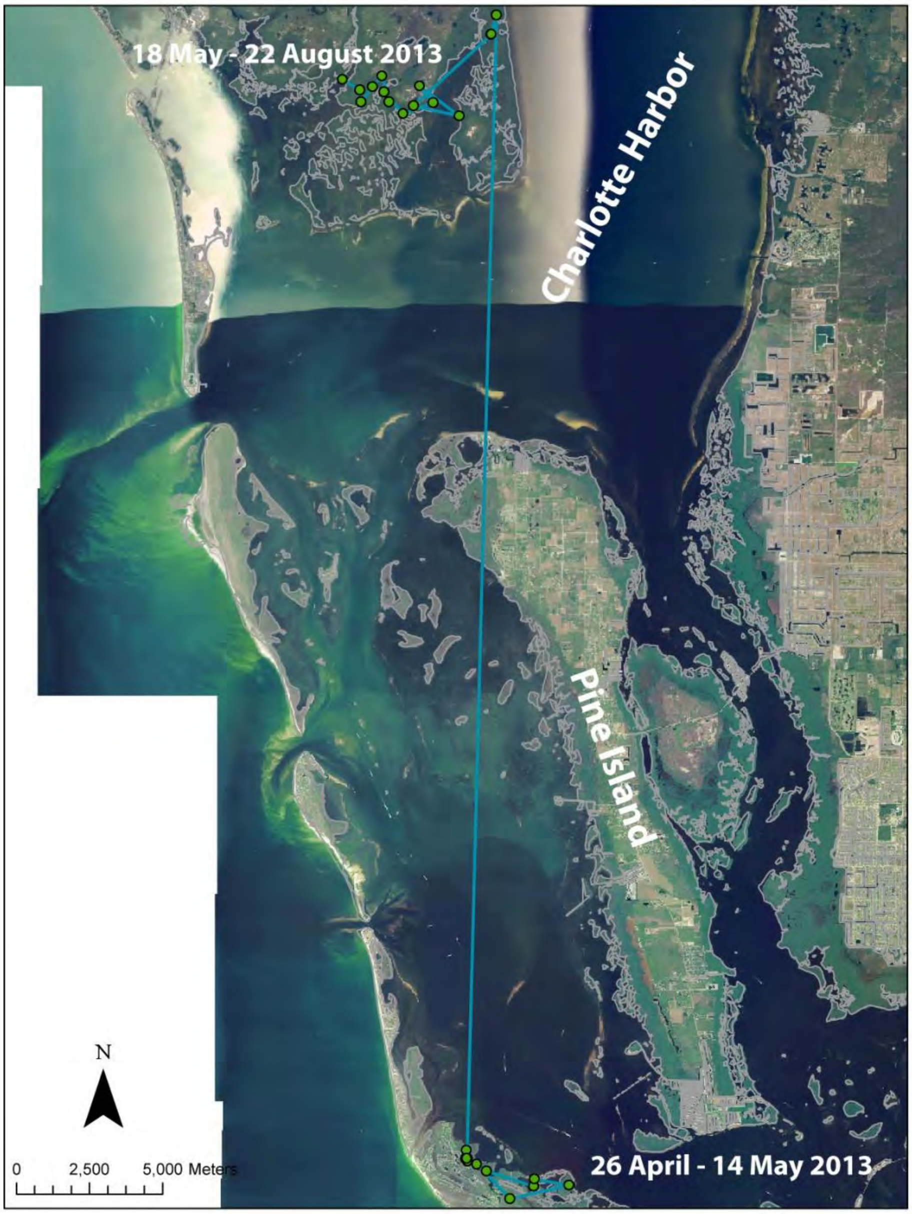

Figure 2. Individual 150.928 was captured 26 April 2013 near the LCEC power line along Wildlife Drive in J. N. "Ding" Darling National Wildlife Refuge. This bird remained on and near the Refuge through 14 May 2013. It was relocated approximately 40 km north of the Refuge at Charlotte Harbor Preserve State Park during an aerial search on 18 May 2013. It remained in this area through 22 August 2013, after which time it was not relocated despite continued aerial searches in the area.

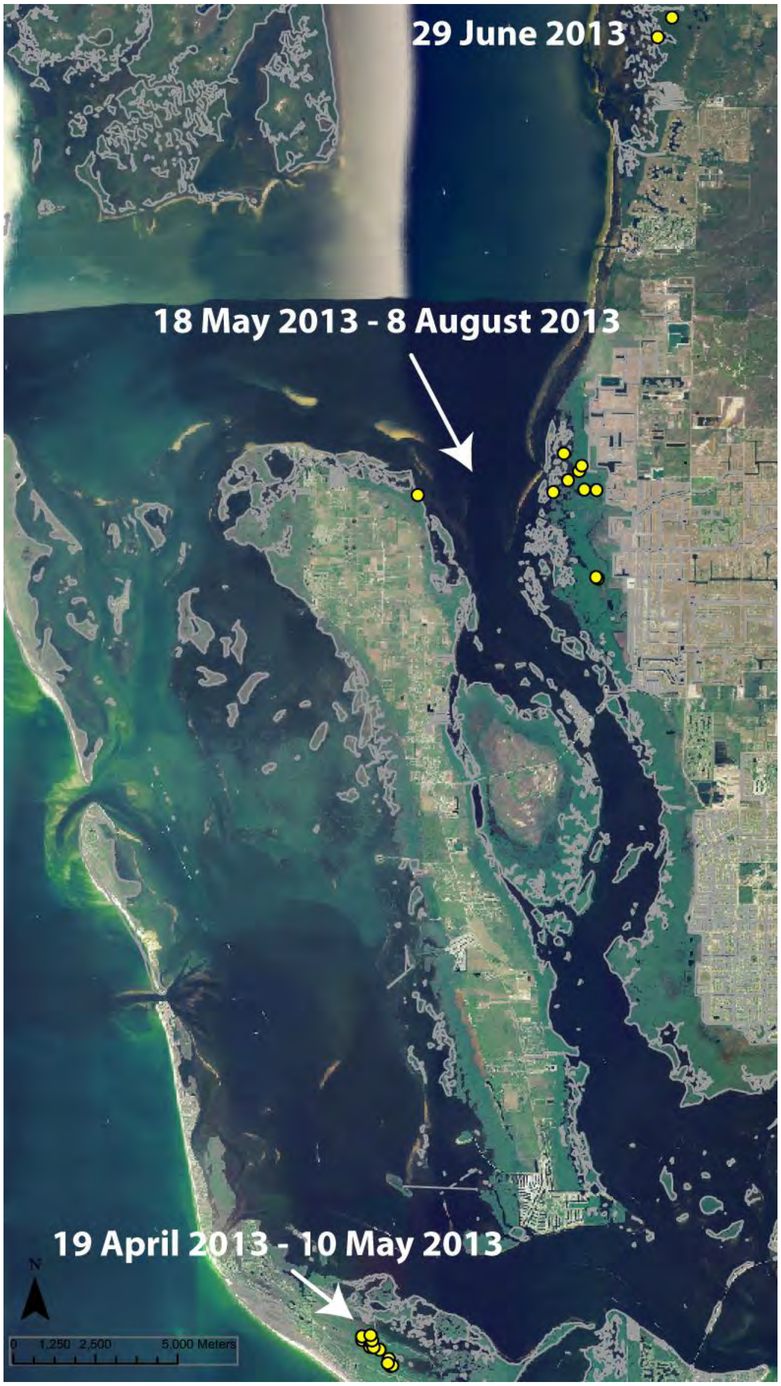

Figure 3. Individual 150.765 was captured on J.N. “Ding” Darling National Wildlife Refuge on 19 April 2013, where it remained until at least 10 May 2013. Sometime between 10 May and 18 May 2013 it relocated to north of Matlacha Pass (a straight line flight of roughly 25 km), where it remained until at least 8 August 2013. It was not detected during subsequent aerial searches of the area.

Figure 4. Individual 150.874 was captured near the entrance booth to Wildlife Drive on 15 March 2013. It remained on the Refuge until at least 15 July 2013, after which it was not detected during aerial or ground searches. The expected date of failure for the transmitter battery was 5 September 2013.

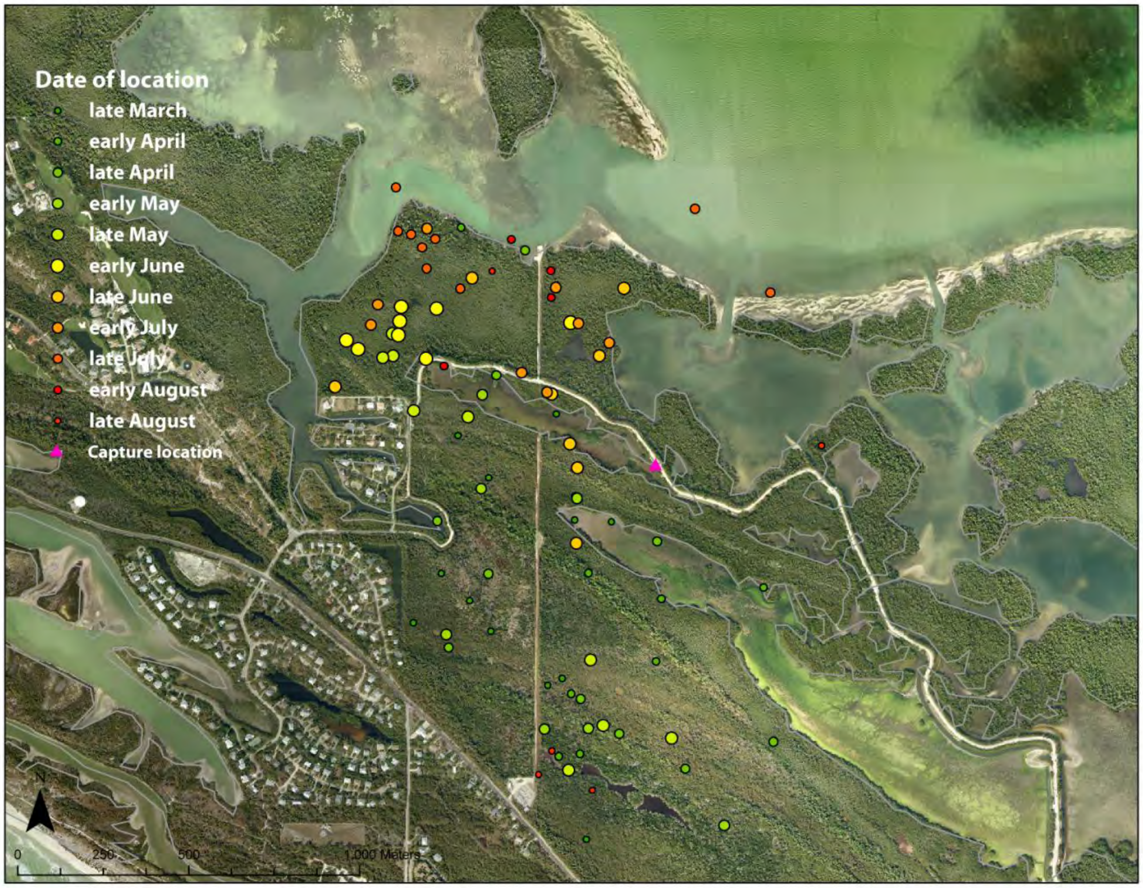

Figure 5. Individual 150.883 was captured on 16 March 2013 (pink triangle) and occupied the area until at least 30 August 2013, after which point it was no longer detected. The nominal failure date for the transmitter battery was 6 September 2013. This individual shifted northwest as the season progressed (yellower, larger points), before returning to the southeast end of the Lee County Electric Cooperative power line (redder, smaller points), which it had occupied early in the spring (greener, smaller points). However, seasonal shifts in location were not clear-cut (e.g., it occurred in the northwest corner of the putative home range in every month from March – August).

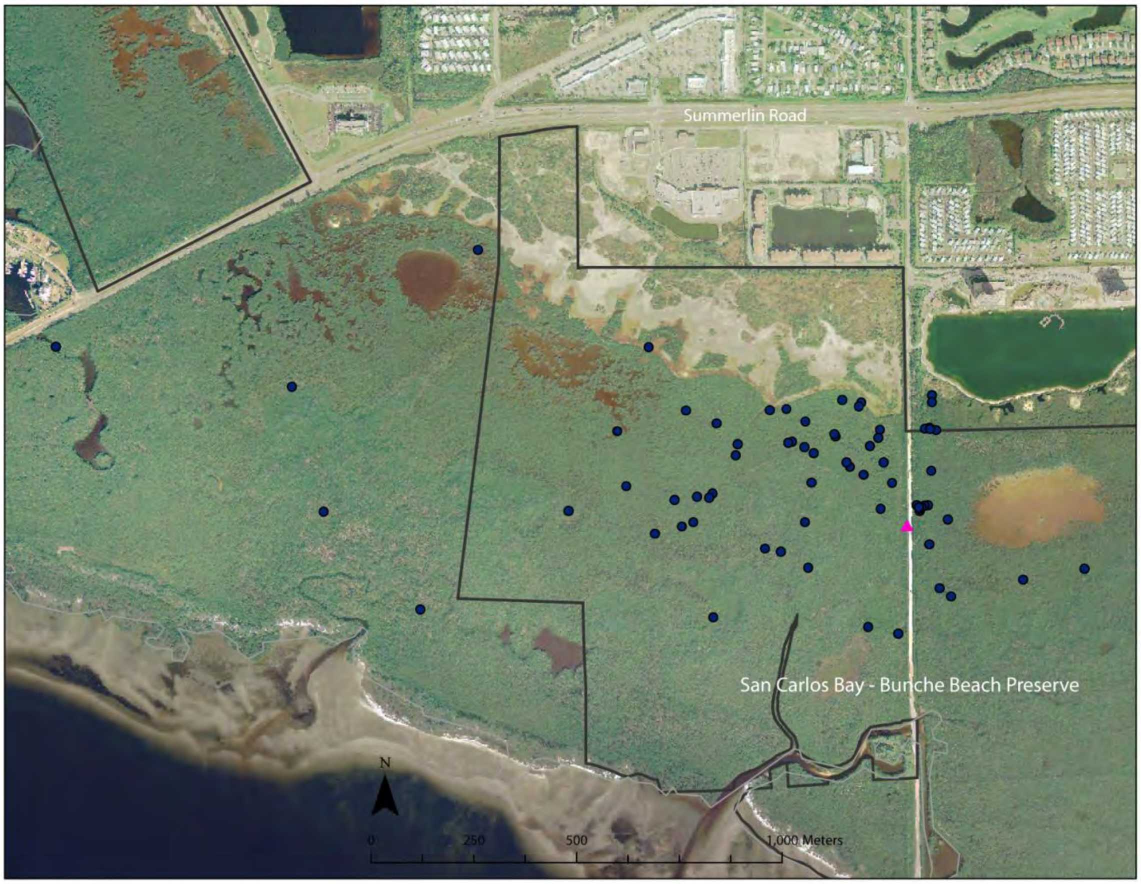

Figure 6. Individual 150.775 was captured (pink triangle) on John Morris Road on 14 May 2013, and remained in and around the San Carlos Bay – Bunche Beach Preserve until at least 9 September 2013, after which point it was not detected either during ground or aerial searches. The nominal date of failure for the radio-transmitter battery was 24 September 2013.

Figure 7. Individual 150.757 spent May - July on the west side of Tarpon Bay (green and orange points). At the beginning of August, it began moving further afield, eventually travelling north to Little Pine Island, where it spent at least 2 weeks. It was not located after 22 August 2013 despite several aerial searches of the area. The nominal failure date for the battery in the radio transmitter was 19 September 2013.

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 perhaps until August. 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 obtained our first direct evidence of local breeding by Mangrove Cuckoos. On 13 July, we observed a group of 4 Mangrove Cuckoos, of which 2 were believed to be hatch-year birds that were still associating with their parents (Fig. 8). The key features that led us to believe that these were hatch-year birds were the pattern of coloration on the retrices, which lacked the characteristic bold black and white seen in adults; the lack of wear on the retrices, which is incompatible with feathers that would have been molted nearly 9 months earlier had these been adults; and the noticeably buffy edging to primary coverts and greater coverts (Fig. 8). Both of the putative hatch-year birds appeared similar in size to the putative adults accompanying them, and both were fully feathered, suggesting that they had fledged at least 3-4 weeks earlier. This suggests that nest initiation began sometime in late May or early June, assuming that eggs require 11 days of incubation time and that the nestling period lasts roughly 7 days. Initiation of nesting in late May or early June would fit with the movement patterns we have previously described, wherein some individuals disperse from areas that they have occupied during the late winter and early spring to establish new home ranges during the middle of May.

Figure 8. A Mangrove Cuckoo believed to have hatched sometime in early to mid-June. Note the distinct buffy edges to the greater coverts and the immaculate condition of the retrices. Note also the lack of a bold black-and-white pattern to the retrices. Note finally the yellow eye-ring, historically considered a characteristic of adults, but which instead appears to be a seasonal, and not age-related, trait.

Although the presence of hatch-year birds in July and the patterns of seasonal movement described earlier suggest a May – August breeding season, we note that other cuckoos show highly variable breeding phenology, and that further investigation may prove that Mangrove Cuckoos have a broader breeding season that currently believed. For example, 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. Estimated home-range size varies widely among individuals and among methods. Generating more precise and accurate estimates of home-range size will require better information on the activity of each bird at the time it is located.

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 the 8 individuals with an adequate number of relocations. For individuals that we monitored over long periods of time that may have spanned breeding and non-breeding periods, we attempted to use only locations that reflected the breeding-season home range. However, we had no information on the activities of any of our marked birds at the times that we gathered data on location, so our censoring tactic was crude.

For birds that appeared to relocate to a distinct and different home range during May or June (e.g., Figs. 1 and 2), we used only those locations gathered after the putative relocation. For individuals that did not relocate prior to the putative breeding season, we examined the distribution of locations as a function of date and subjectively determined whether a cluster of points could be distinguished during the putative breeding season (May – August). If we could identify such a cluster (e.g., Fig. 4), then we censored all other locations for the purpose of estimating the boundaries of the breeding season home range. If we could not distinguish any seasonal pattern in the distribution of locations, then we used all locations and censored none (e.g., Fig. 5). In all cases, locations that fell over open water, which we assume reflect telemetry error, were excluded from these analyses.

We used the heuristics provided by Getz et al. (2007) to parameterize the estimator and calculated the 50% (core area), 90%, and 100% isopleths 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.

For the purposes of comparison, we also generated the minimum convex polygon and the fixed kernel-density estimate of the home range. For the kernel-density analysis, we estimated the value of the smoothing parameter for the kernel (*h*) using likelihood cross-validation, which appears to perform better with small sample sizes (Horne and Garton 2006). Following the recommendation of Horne and Garton (2006), we examined plots of the likelihood function across a range of values for *h* to determine whether multiple minima existed. We found that the estimate of *h* produced by likelihood cross-validation tended to overfit the data when sample sizes were small, producing isolated patches of home range separated by areas of putatively unused space (e.g., compare Fig. 9 and Fig. 10). When, in our opinion, the home-range boundaries were overfit, we used the value of *h* as calculated using the method in Worton (1995) because it tended to be more conservative and produced fewer potentially spurious gaps in the home range.

Home-range location and size

Estimated home-range sizes were large but varied widely among individuals and among methods (Table 2). 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). 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). If borne out, this pattern would 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.

Although it does appear that Mangrove Cuckoos require fairly large areas of habitat, we suspect that many of our estimates of home-range size are inflated due to conflating locations taken during distinct phases of the annual cycle of the bird. For example, if birds move greater distances when they are not raising young, then combining location data from before, during, and after breeding – as we almost certainly have done in some cases – will yield an artificially large home range. The only way to avoid this problem is to collect ancillary data on the activity of each bird at the time that locations are estimated, which would allow us to link the location data with the distinct phases of the annual cycle (e.g., breeding).

In addition to the information on the size and location of home ranges (Figs. 11-18), the estimated home-range boundaries also revealed two interesting social interactions. In one case, the home ranges of two individuals using adjacent areas showed a very clear boundary and were nearly exclusive of each other (Fig. 19), as would be expected under a territorial defense system of sociality. One the other hand, the almost complete overlap in the core areas of the home range of two individuals suggested that they may have been a mated pair (Fig. 20).

Table 2. Estimated home-range sizes of Mangrove Cuckoos captured and radio-tracked in and around Sanibel, Florida during 2013.

		Local convex hulls (ha)			Minimum convex polygon (ha)	Fixed kernel-density estimate (ha)				
Individual	Year	Core use area (50% isopleth)	90% isopleth	100% isopleth		*h*[a]	Core use area (50% volume contour)	90% volume contour	100% volume contour	N
150.613	2013	36.2	153.3	234.1	422.1	222	80.2	317.9	1040.0	48
150.928	2013	167.9	299.1	377.8	930.5	513	340.3	659.5	2,269.0	15
150.865	2013	35.8	94.4	219.3	265.9	60	62.8	186.2	527.3	57
150.874	2013	215.5	489.6	805.8	1,171.5	167	402.4	1,008.3	2,925.4	34
150.883	2013	209.0	790.8	1,582.3	1,714.3	212[b]	667.1	1,208.1	4,290.8	81
150.757	2013	7.5	31.2	44.7	61.3	113	21.2	49.6	123.0	31
150.775	2013	6.7	41.0	120.9	140.4	164	24.9	80.6	344.1	69
150.819	2013	12.2	45.4	95.4	119.5	134	28.7	89.9	216.2	41
	Average	86.35	243.1	435.04	603.19		203.45	450.01	1,466.98	
	Minimum	6.7	31.2	44.7	61.3		21.2	49.6	123	
	Maximum	215.5	790.8	1,582.3	1,714.3		667.1	1,208.1	4,290.8	
	CV	1.08	1.12	1.20	1.00		1.18	1.01	1.04	

[a] Estimates of *h* derived using likelihood cross validation (Horne and Garton 2006), unless otherwise noted.
[b] Estimate of *h* generated using the href method of Wooton (1995)

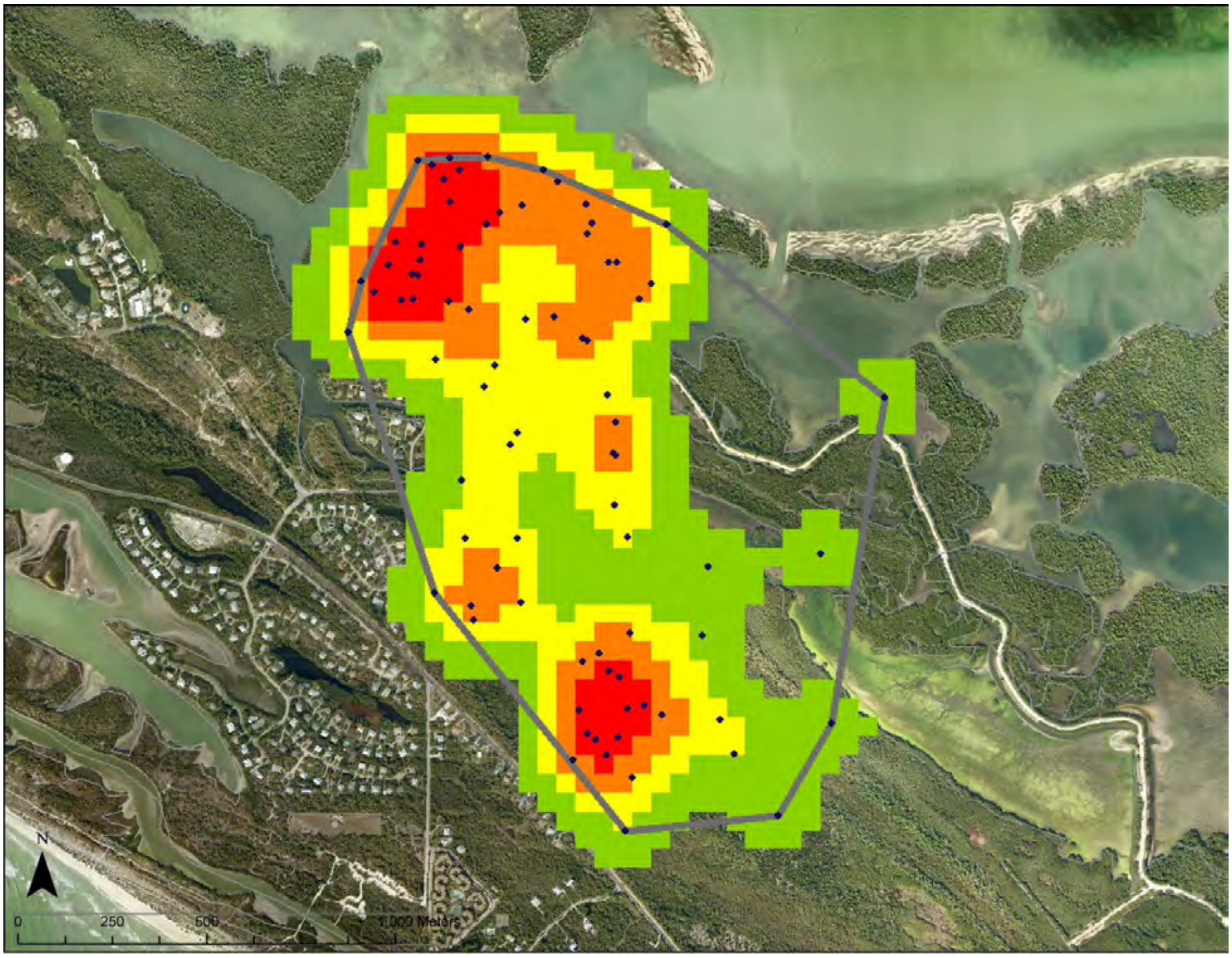

Figure 9. Fixed kernel density estimate (and minimum convex polygon; solid line) of home-range boundaries for individual 150.883. The smoothing parameter used in this analysis was based on the likelihood cross-validation estimate (*h* = 132.4), and appeared to overfit the distribution of points (note the isolated patch of home range surrounding the single point on the center-right side of the figure).

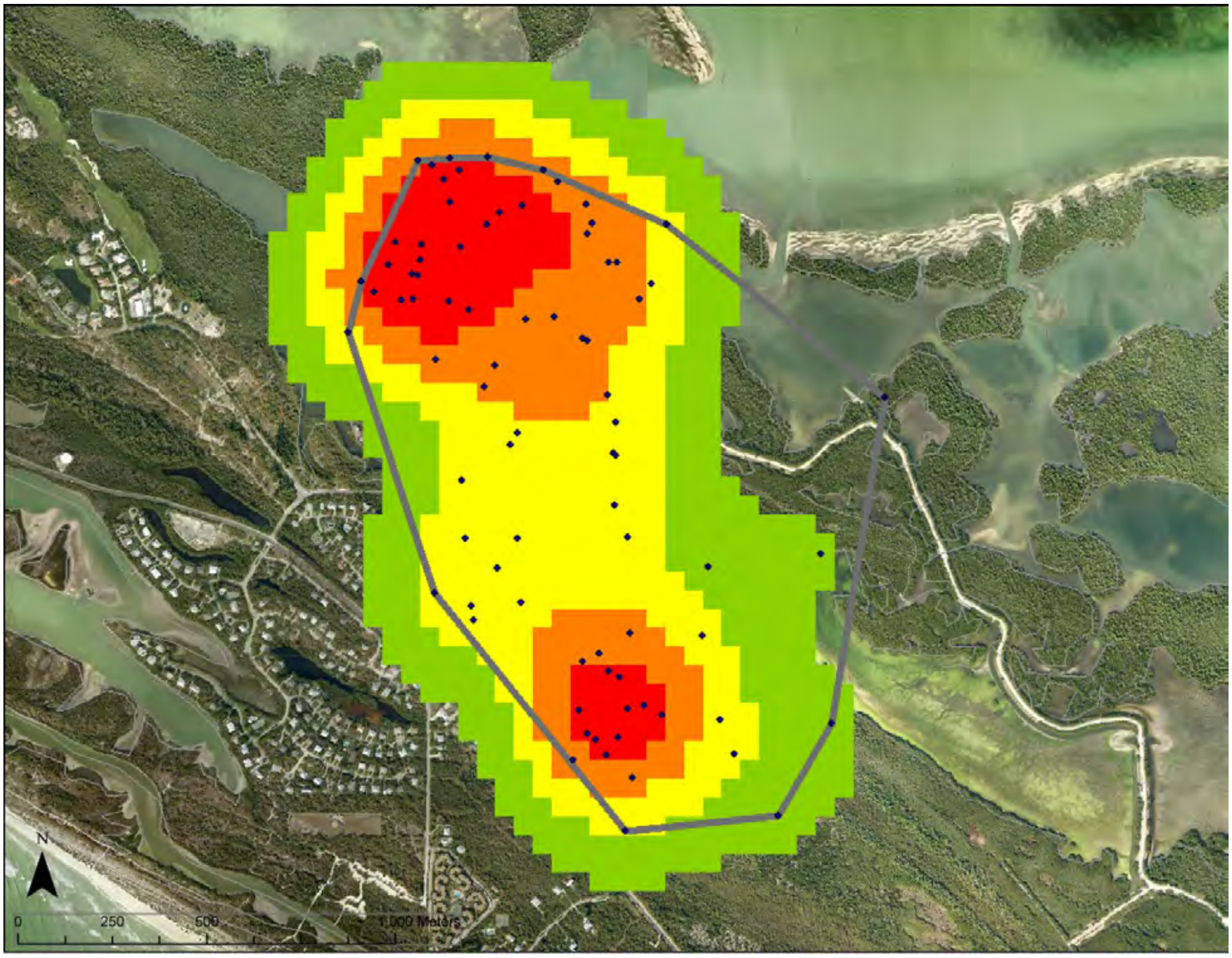

Figure 10. Fixed kernel density estimate (and minimum convex polygon; solid line) of home-range boundaries for individual 150.883. The smoothing parameter (*h* = 212) used in this analysis was based on the href method described in Worton (1995), and appeared to avoid the overfitting seen in Figure 13.

Figure 11. Individual 150.613 (2013) used a core area (50% home-range isopleth) of 36.2 ha based on the home-range boundaries estimated using local convex hulls. Total home-range size (100% home-range isopleth) using this method was 234.1 ha. The core area delineated by the fixed kernel density estimate (50% volume contour) was larger (80.2 ha) but was centered in the same area (not considering the small, disjunct core area near Summerlin Road). The total home-range size (100% volume contour) estimated using the kernel density estimates was substantially larger (1,040 ha) and included open water, built environments, and other uninhabitable spaces. The minimum convex polygon estimate of home range (solid black line) was intermediate in size between the other two methods.

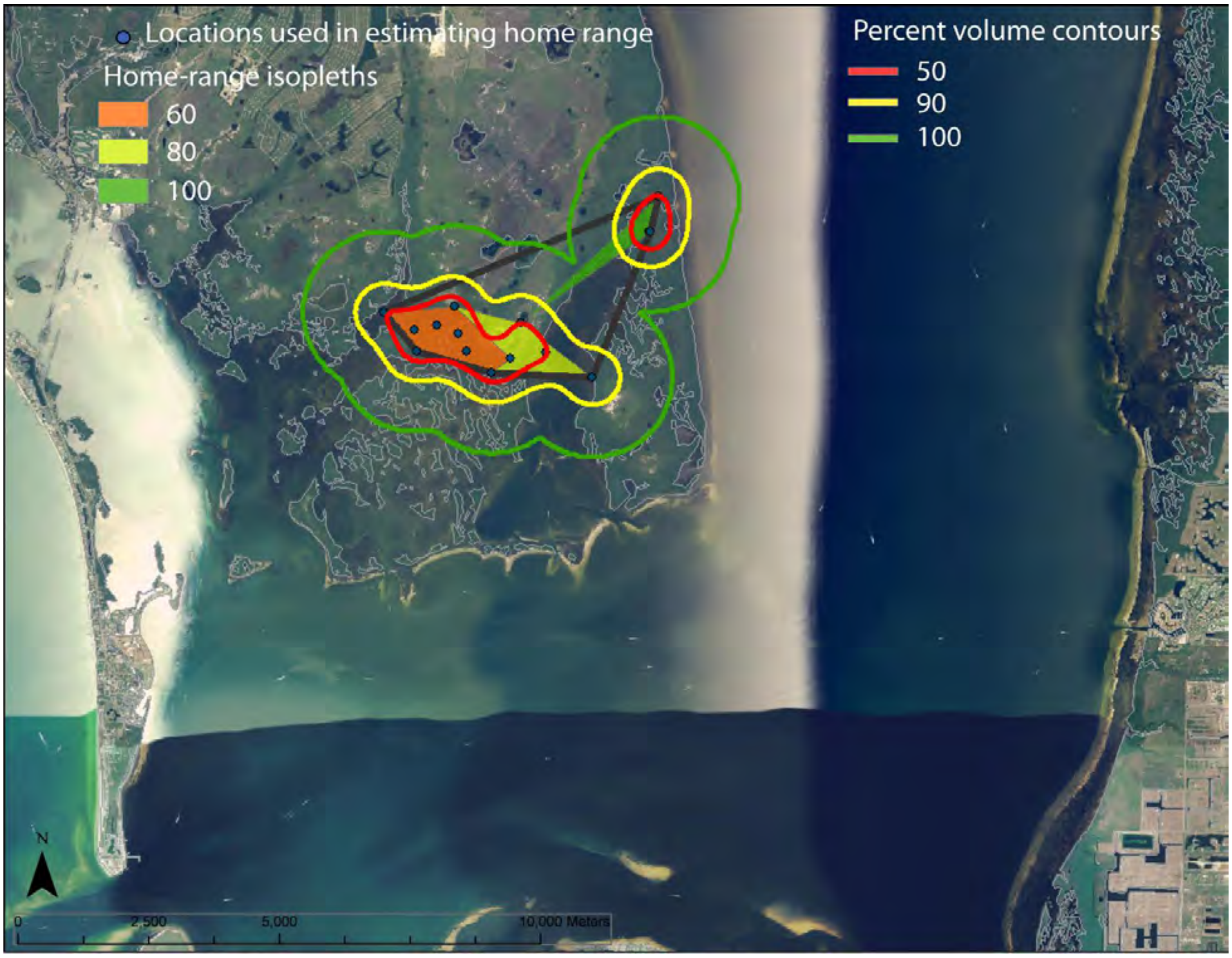

Figure 12. Individual 150.928 (2013) used a core area (60% home-range isopleth; sample size was too small to estimate the 50% isopleth) of 167.9 ha. Total home-range size (100% home-range isopleth) was 377.8 ha. The estimate of home-range size based on the fixed kernel density estimate was much larger, with a core area of 340.3 ha (50% volume contour) and a total home range of 2,269.0 ha (100% volume contour). The minimum convex polygon (solid black line) was 930.5 ha.

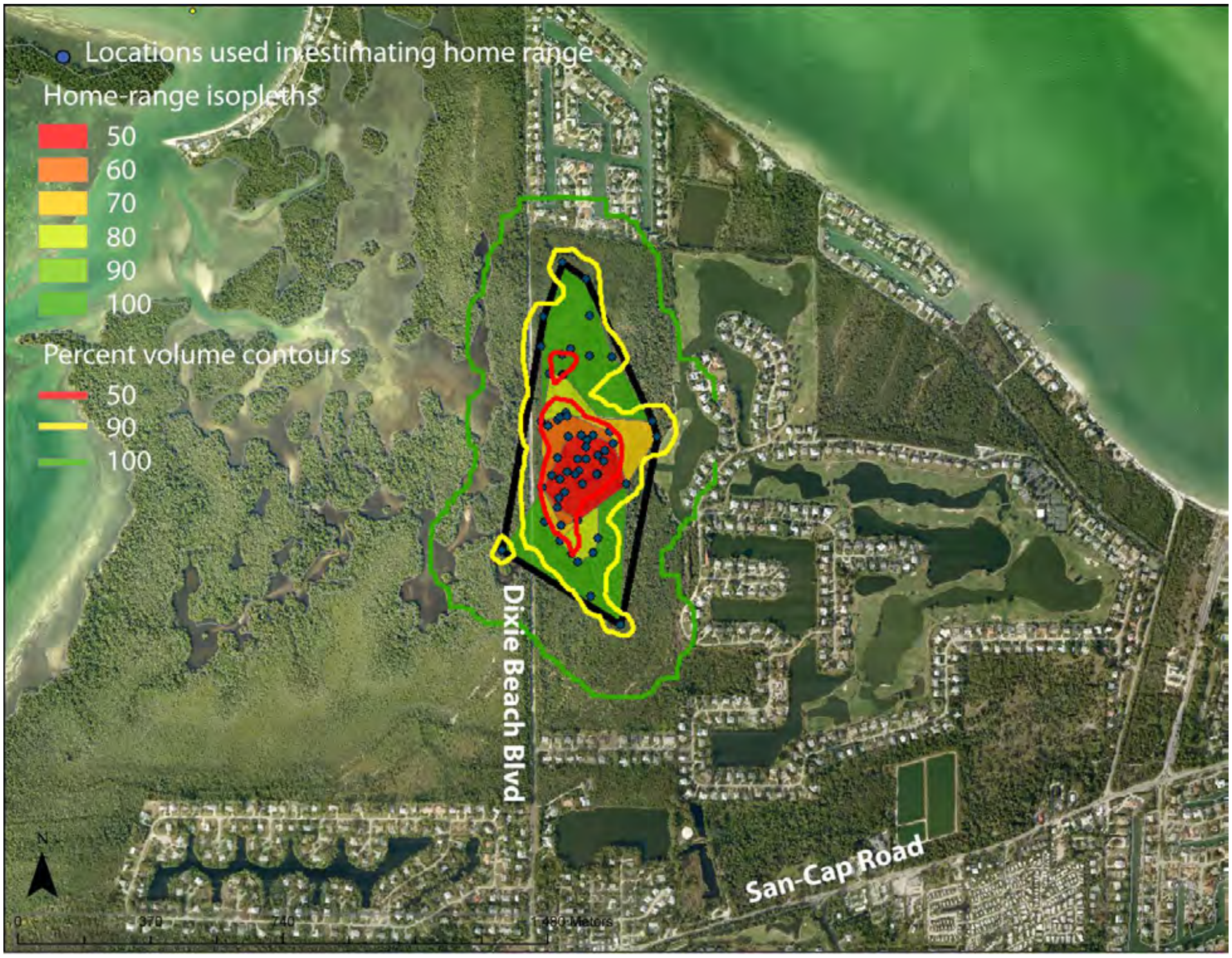

Figure 13. Individual 150.865 was captured on 21 May 2013 along Dixie Beach Boulevard. It was present in the area through 6 September 2013 (but exact locations were only estimated through 22 August 2013), at which point the battery on its transmitter is believed to have failed. This bird used a core area (50% home-range isopleth) of 36.2 ha based on the home range described using local convex hulls. Total home-range size (100% home-range isopleth) was 234.1 ha using this same method. The home-range boundaries described by the fixed kernel density estimate were generally broader, with an estimated core area of 62.8 ha (50% volume contour) and a total home-range size of 527.3 ha (100% volume contour). The minimum convex polygon estimate of home-range size (265.9 ha; solid black line) was similar to the total home-range size described using local convex hulls.

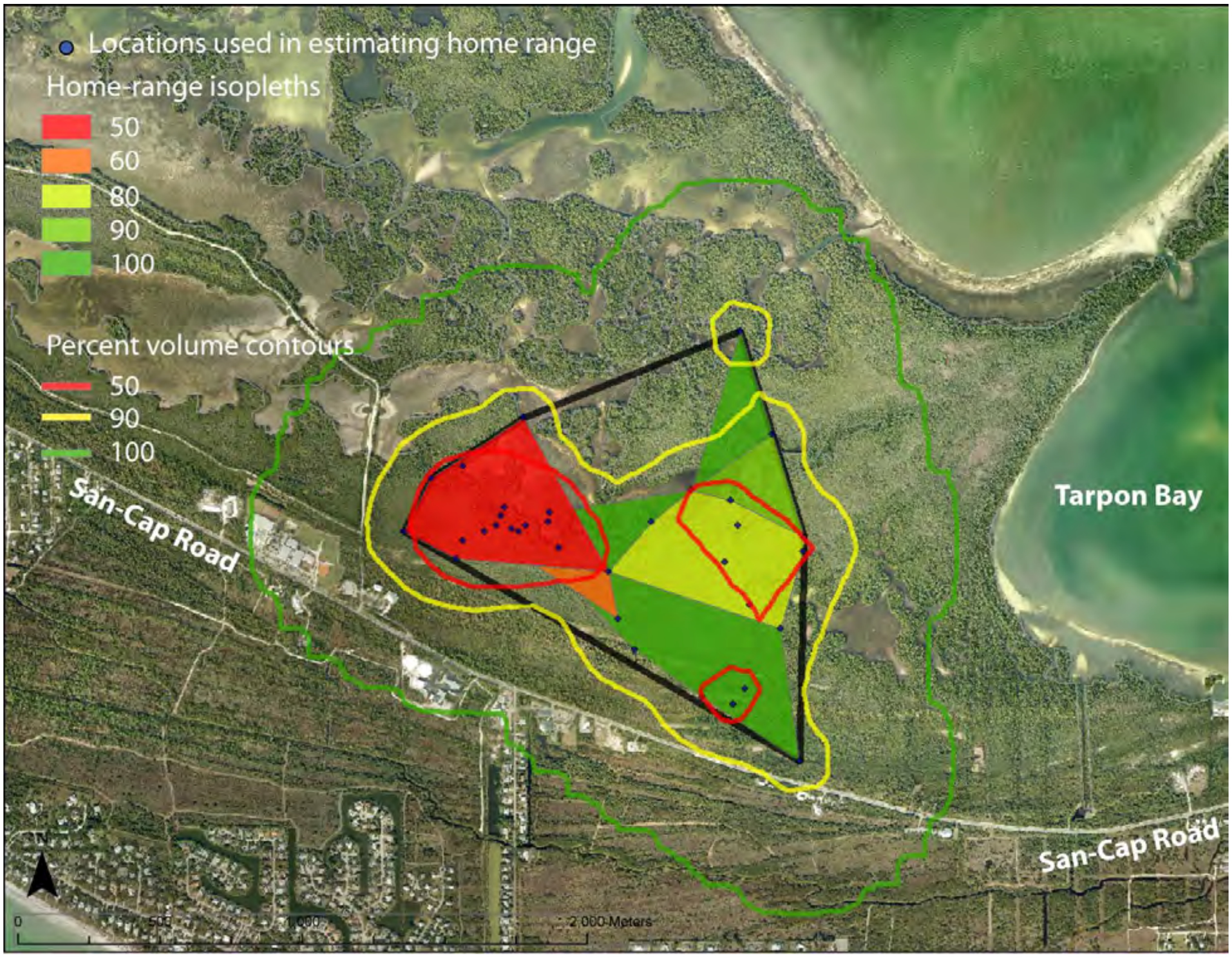

Figure 14. Individual 150.874 was captured on 15 March 2013 on Wildlife Drive near the entrance booth. It remained on the Refuge until at least 15 July 2013, after which it was not detected. This period likely included pre-breeding and breeding activities. To promote comparability with other individuals only followed during the breeding season, only those locations between 15 May 2013 and 15 July 2015 were used to estimate home-range boundaries. This bird used a core area (50% home-range isopleth) of 215.5 ha, based on estimates derived from local convex hulls. Total home-range size using this method (100% home-range isopleth) was 805.8 ha. The home-range size derived from fixed kernel density estimates was also large; core-use area was estimated at 402.4 ha (50% volume contour) and total home-range size was 2,925.4 ha (100% volume contour). The exceptionally large size of estimated home range may reflect the inclusion of locations not used during breeding.

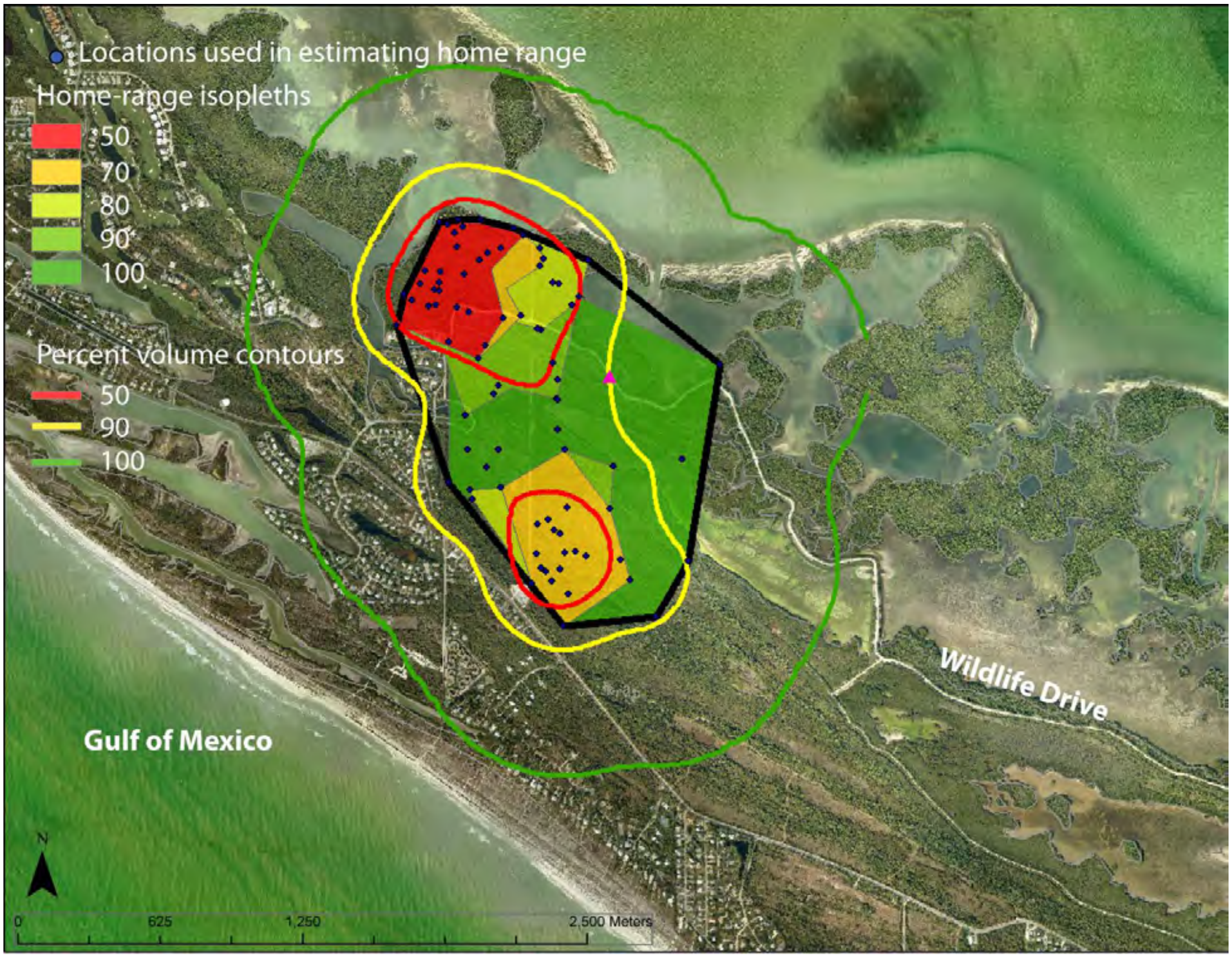

Figure 15. Home-range boundaries for individual 150.883 generated using local convex hulls (isopleths) and fixed kernel density estimates (percent volume contours). This bird was tracked over a long period of time and the distinct areas of concentrated use (orange and red polygons) may reflect a seasonal shift in home-range use, from the southeast portion of the figure in winter to the northwest portion of the figure during summer. This bird used a core area (50% home-range isopleth) of 209.0 ha. Total home-range size (100% home-range isopleth) was 1,582.3 ha, but this probably includes areas not used during breeding. Home-range size based on the kernel density estimates was larger; the core-use area was 667.1 ha (50% volume contour), and the total home-range size was 4,290.8 ha (100% volume contour).

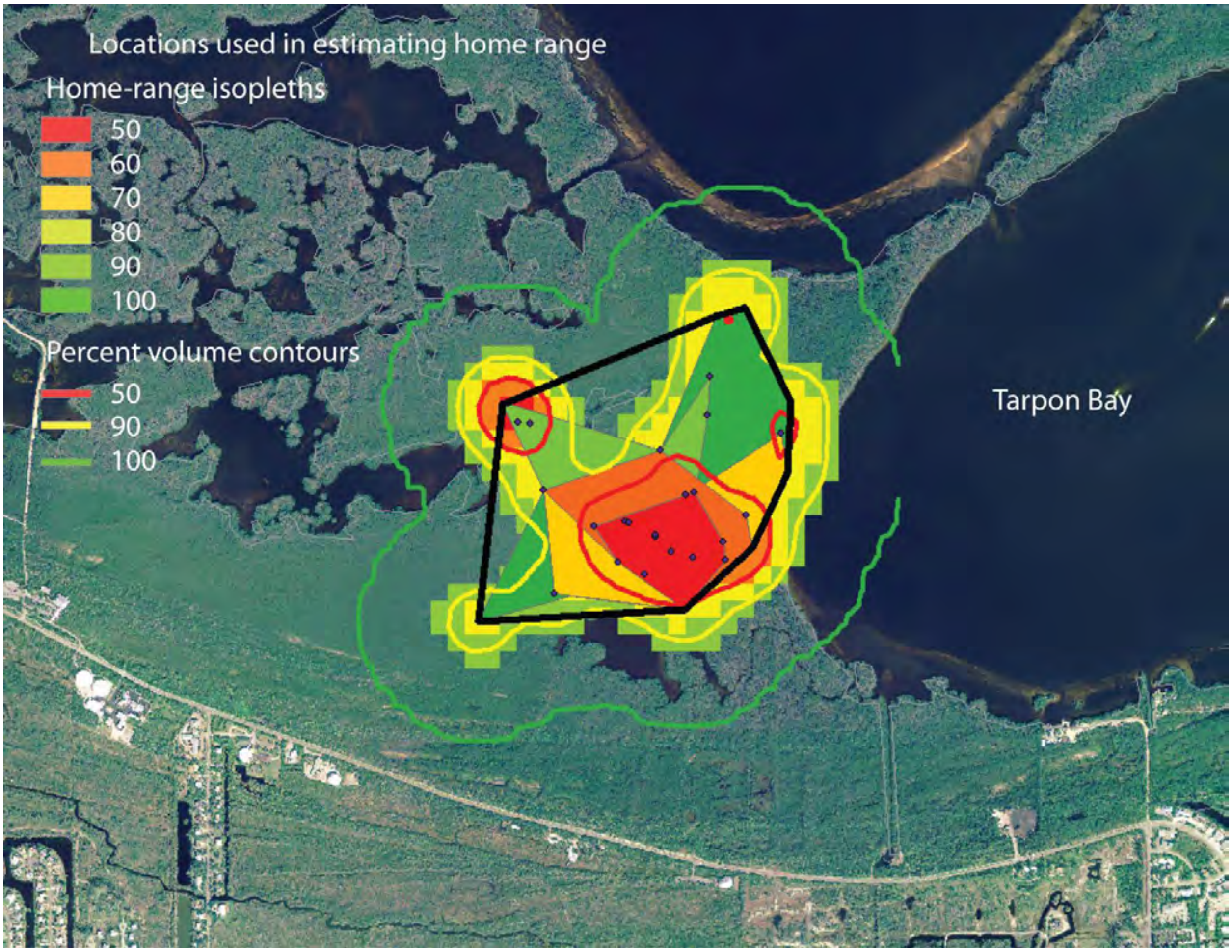

Figure 16. Home-range boundaries for individual 150.757 generated using local convex hulls (isopleths) and fixed kernel density estimates (percent volume contours). This bird used a core area (50% home-range isopleth) of 7.5 ha. Total home-range size (100% home-range isopleth) was 44.7 ha. Home-range size based on the kernel density estimates was larger; the core-use area was 21.2 ha (50% volume contour), and the total home-range size was 123.0 ha (100% volume contour).

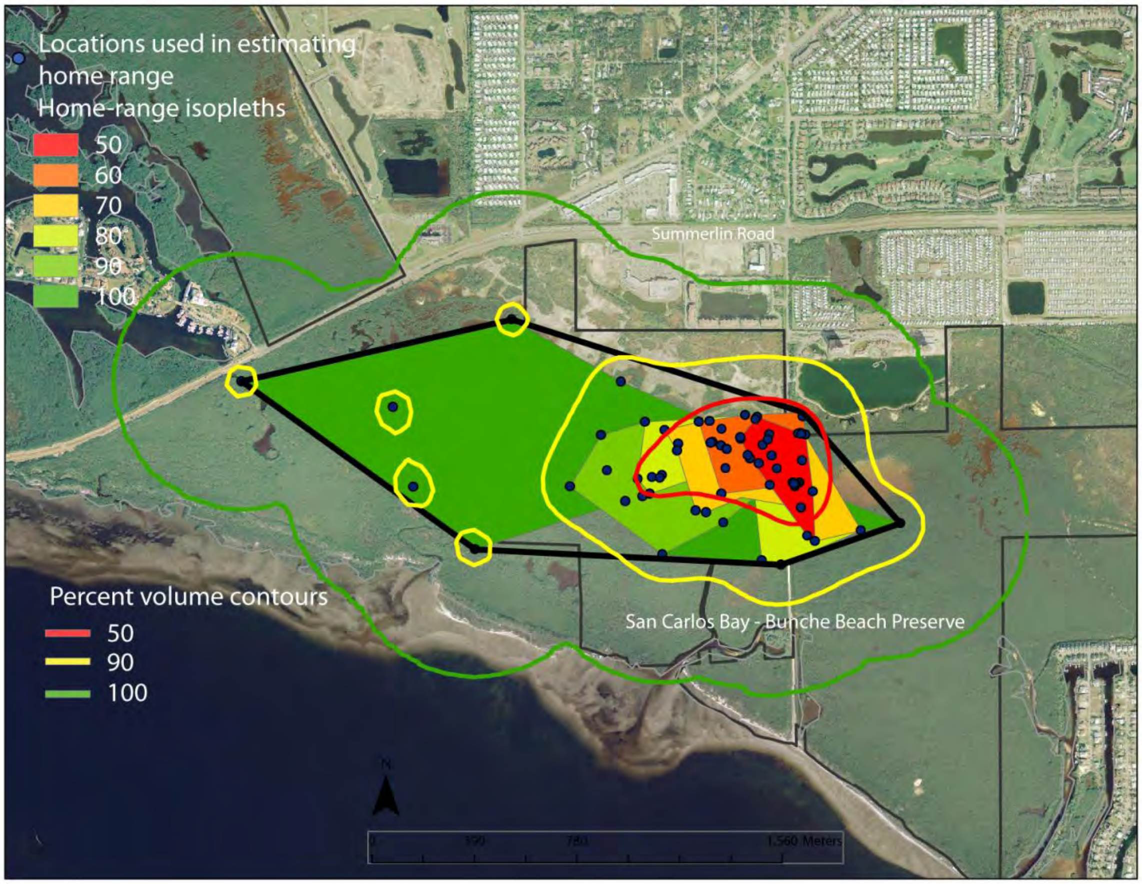

Figure 17. Home-range boundaries for individual 150.775 generated using local convex hulls (isopleths) and fixed kernel density estimates (percent volume contours). This bird used a core area (50% home-range isopleth) of 6.7 ha, based on the local convex hulls estimate of home range. Total home-range size (100% home-range isopleth) using this method was 120.9 ha. Home-range size based on the kernel density estimates was larger; the core-use area was 24.9 ha (50% volume contour), and the total home-range size was 344.1 ha (100% volume contour). The minimum convex polygon (solid black line) estimate of home-range size was 140.4 ha. Note that the kernel density method appears to give undue weight to the five westernmost locations, which may represent exploratory movements.

Figure 18. Home-range boundaries for individual 150.819 generated using local convex hulls (isopleths) and fixed kernel density estimates (percent volume contours). 150.819 was captured along John Morris Road on 18 June 2013 and remained in this area until at least 27 August 2013, after which it was not relocated during ground or aerial searches. The nominal failure date for the transmitter battery was 28 October 2013. This bird used a core area (50% home-range isopleth) of 12.2 ha, based on the local convex hulls estimate of home range. Total home-range size (100% home-range isopleth) using this method was 95.4 ha. Home-range size based on the kernel density estimates was larger; the core-use area was 28.7 ha (50% volume contour), and the total home-range size was 216.2 ha (100% volume contour). The minimum convex polygon (solid black line) estimate of home-range size was 119.5 ha.

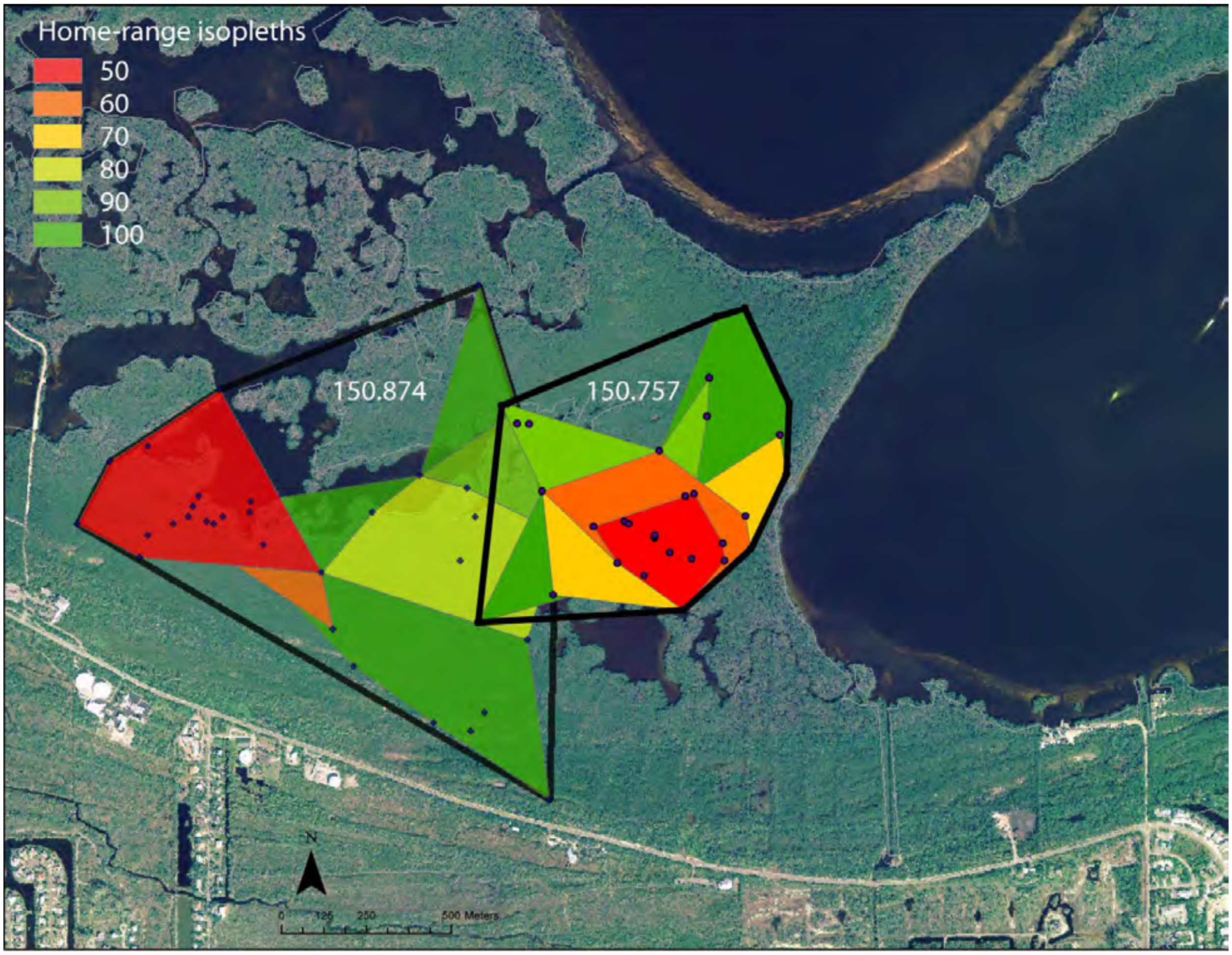

Figure 19. Individuals 150.874 and 150.757 had non-overlapping home ranges (shown here as the minimum convex polygon [solid black line] and the local convex hulls [isopleths]) that were used during the same time period, suggesting the possibility of territoriality and home-range defense.

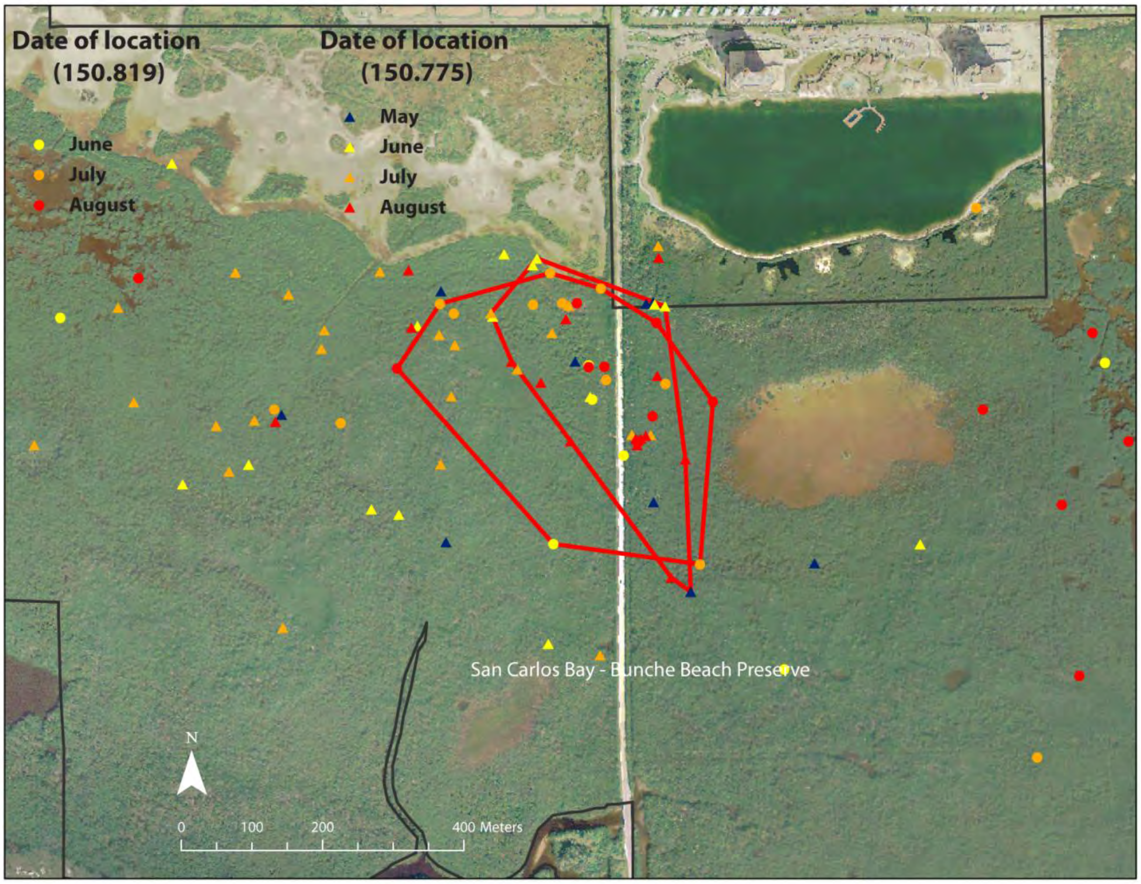

Figure 20. Core areas (red lines) in the home ranges of individuals 150.775 and 150.819, as defined by the 50% isopleths, overlapped completely. Temporal use of the core areas also overlapped; based on the estimated locations of 150.775 (triangles) and 150.819 (circles), both individuals used the core areas during June – August. 150.775 remained in this area until at least 9 September 2013, whereas 150.819 was not relocated after 27 August 2013.

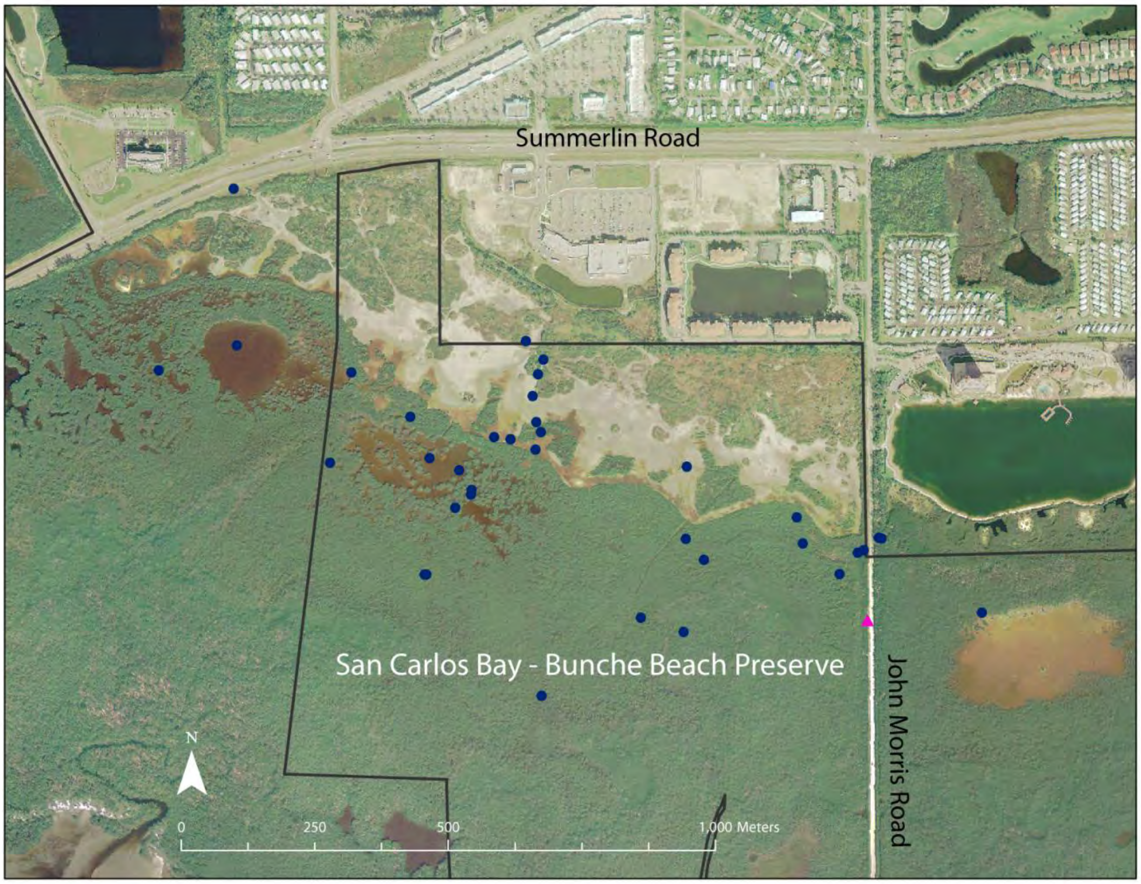

Figure 21. Estimated locations for 150.829, which was captured along John Morris Road (pink triangle shows capture site) on 9 July 2013. It used this area until at least 26 September 2013, after which point it was not detected. The nominal failure date for the radio-transmitter battery was 19 November 2013. We did not attempt to estimate a home range for this individual due to the timing of capture, which may have been post-breeding, and the relative paucity of estimated locations.

CONSERVATION AND MANAGEMENT IMPLICATIONS

Nearly all of the locations at which we found Mangrove Cuckoos during 2013 were located on public land or land that was otherwise conserved (Fig. 22), highlighting the importance of land protection for the conservation of this species and others that inhabit the mangrove forests and shrublands of south Florida.

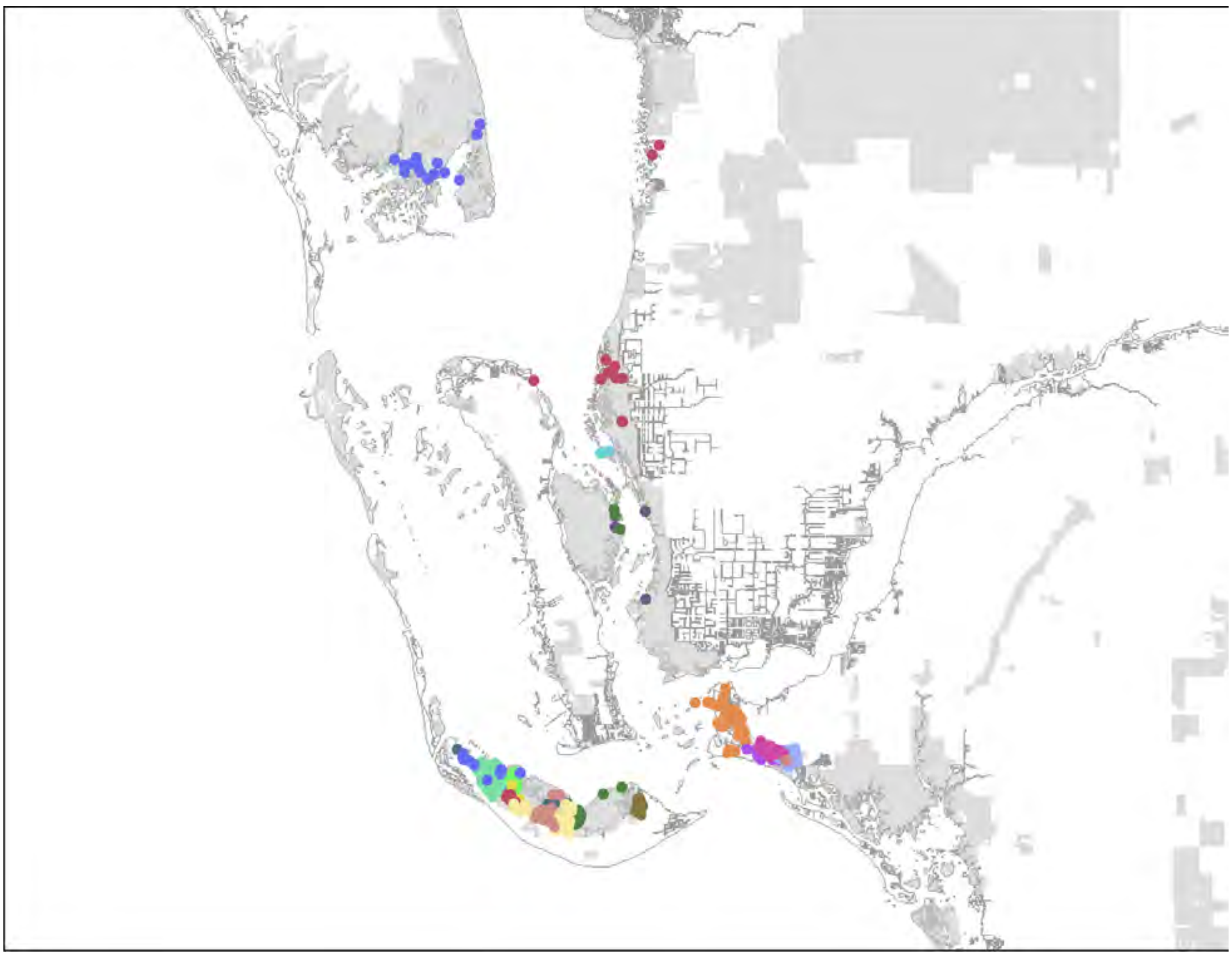

Figure 22. Public land (areas shaded in gray) plays an important role in the conservation of Mangrove Cuckoos and other species that depend on mangrove forests and shrublands. Nearly 81% (n = 569) of estimated locations obtained from radio-marked birds in 2012 and 2013 (colored dots show estimated locations of different individuals) were on public lands (not included are privately held land under conservation easements), including J. N. “Ding” Darling National Wildlife Refuge, Matlacha Pass National Wildlife Refuge, San Carlos Bay – Bunche Beach Preserve, Norberg Research Natural Area, Estero Bay Preserve State Park, Charlotte Harbor Preserve State Park, and Charlotte Harbor Buffer Preserve.

As in 2012, we found that Mangrove Cuckoos occupied large home ranges during what we believe is the breeding season. Although we suspect that we may have overestimated the average size of home ranges and the extent of variation in home-range size among individuals, it nonetheless appears that Mangrove Cuckoos require at least 30 ha of mangrove forest when nesting (if we use the 90% isopleth from the local convex hulls as the measure of home-range boundaries). They do not appear to avoid artificial edges (see Figs. 11, 13, 17 and 18) although we do not know whether edge effects on reproductive success occur.

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, Charlotte Harbor Buffer Preserve, Matlacha Pass National Wildlife Refuge, and San Carlos Bay-Bunche Bay Preserve. Given patterns of land ownership, conservation of Mangrove Cuckoos in the region will require collaboration between county, state, and Federal agencies.

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