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## Conservation status of Grand Cayman (*Amazona leucocephala caymanensis*) and Cayman Brac (*Amazona leucocephala hesterna*) Parrots

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**A Special Issue on the Status of Caribbean Forest Endemics**

## Conservation status of Grand Cayman (*Amazona leucocephala caymanensis*) and Cayman Brac (*Amazona leucocephala hesterna*) Parrots

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**Abstract** Two subspecies of Cuban Parrot (*Amazona leucocephala*; hereafter Grand Cayman Parrot and Cayman Brac Parrot [for singular] or Cayman Islands Parrots [for plural]) inhabit the Cayman Islands—the Grand Cayman Parrot (*A. l. caymanensis*) and the Cayman Brac Parrot (*A. l. hesterna*). Both subspecies are threatened by habitat loss, hunting by farmers, the collection of nestlings, and hurricanes. Herein, we use before-after reproduction distance sampling surveys to assess the conservation status of parrots in the Cayman Islands. On Grand Cayman, estimated density (parrots ha<sup>-1</sup>) increased from 0.172 ± 0.026 SE (95% CI = 0.128, 0.210) in August 2005 to 0.411 ± 0.077 (0.279, 0.578) in August 2014 ( $Z = -2.94$ ,  $p = 0.002$ ). The estimated population size was 6,395 ± 1,202 (4,340, 8,987) parrots after reproduction on Grand Cayman in 2014. On Cayman Brac, estimated density increased from 0.160 ± 0.021 (0.116, 0.222) in July 2008 to 0.219 ± 0.028 (0.171, 0.280) in July 2015 ( $Z = -1.69$ ,  $p = 0.09$ ). The estimated population size was 772 ± 97 (603, 989) parrots after reproduction on Cayman Brac in 2015. Parrot distribution became more concentrated in fewer sites on both islands, probably as a result of habitat loss, which in combination with other anthropogenic disturbances can decrease population resiliency to hurricanes. The populations' rates of change from before to after reproduction suggested a small number of breeding pairs on both islands. Therefore, based on our results and adopting IUCN categories locally, we recommend classifying the Grand Cayman Parrot as Vulnerable and the Cayman Brac Parrot as Endangered.

**Keywords** *Amazona leucocephala caymanensis*, *Amazona leucocephala hesterna*, conservation status, distance sampling

**Resumen** Estado de conservación de la Cotorra de Gran Caimán (*Amazona leucocephala caymanensis*) y la Cotorra de Caimán Brac (*Amazona leucocephala hesterna*)—Dos subespecies de *Amazona leucocephala* habitan las islas Caimán; en lo adelante las cotorras de Gran Caimán y Caimán Brac [para el singular] o cotorras de las islas Caimán [para el plural] – la Cotorra de Gran Caimán (*A. l. caymanensis*) y la de Caimán Brac (*A. l. hesterna*). Ambas subespecies están amenazadas por la pérdida de hábitat, la caza por parte de los agricultores, la colecta de pichones y los huracanes. Aquí utilizamos el método de medición de distancia para efectuar muestreos antes y después de la reproducción y evaluar el estado de conservación de las cotorras en las islas Caimán. En Gran Caimán, la densidad estimada (cotorras ha<sup>-1</sup>) aumentó de 0,172 ± 0,026 ES (IC de 95% = 0,128, 0,210) en agosto de 2005 a 0,411 ± 0,077 (0,279, 0,578) en agosto de 2014 ( $Z = -2,94$ ,  $p = 0,002$ ). El tamaño poblacional estimado en 2014, en Gran Caimán, fue 6.395 ± 1.202 (4.340, 8.987) individuos después de la reproducción. En Caimán Brac, la densidad estimada aumentó de 0,160 ± 0,021 (0,116, 0,222) en julio de 2008 a 0,219 ± 0,028 (0,171, 0,280) en julio de 2015 ( $Z = -1,69$ ,  $p = 0,09$ ). En esta isla en 2015, el tamaño poblacional estimado fue 772 ± 97 (603, 989) individuos después de la reproducción. En ambas islas, la distribución de las cotorras se hizo más concentrada en pocos sitios probablemente como resultado de la pérdida de hábitat; esto combinado con otros disturbios antropogénicos pueden reducir la resiliencia poblacional a los huracanes. Las tasas de cambio poblacional antes y después de la reproducción sugieren un número pequeño de parejas reproductoras en ambas islas. Por lo tanto, en base a nuestros resultados y adoptando las categorías de UICN localmente, recomendamos que se clasifique a la Cotorra de Gran Caimán como Vulnerable y a la Cotorra de Caimán Brac como En Peligro.

**Palabras clave** *Amazona leucocephala caymanensis*, *Amazona leucocephala hesterna*, estado de conservación, muestreo de distancia

**Résumé** Statut de conservation des sous-espèces de l'Amazone de Cuba présentes aux Îles Caïmans : *Amazona leucocephala caymanensis* et *Amazona leucocephala hesterna*—Deux sous-espèces de l'Amazone de Cuba (*Amazona leucocephala*) vivent aux îles Caïmans : *A. l. caymanensis* et *A. l. hesterna*. Les deux sous-espèces sont menacées par la perte d'habitat, la chasse par les agriculteurs, le prélèvement de jeunes oiseaux et les ouragans. Dans la présente étude, nous avons

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effectué des relevés, avant et après la reproduction, par la méthode du distance sampling, afin d'évaluer l'état de conservation de ces amazones dans les Îles Caïmans. Sur Grand Cayman, la densité estimée (amazones/ha) est passée de  $0,172 \pm 0,026$  SE (95% CI = 0,128, 0,210) en août 2005 à  $0,411 \pm 0,077$  (0,279, 0,578) en août 2014 ( $Z = -2,94$ ,  $p = 0,002$ ). La taille estimée de la population était de  $6.395 \pm 1.202$  (4.340, 8.987) amazones après la reproduction sur Grand Cayman en 2014. Sur Cayman Brac, la densité estimée est passée de  $0,160 \pm 0,021$  (0,116, 0,222) en juillet 2008 à  $0,219 \pm 0,028$  (0,171, 0,280) en juillet 2015 ( $Z = -1,69$ ,  $p = 0,09$ ). La taille estimée de la population était de  $772 \pm 97$  (603, 989) amazones après la reproduction sur Cayman Brac en 2015. La répartition des amazones s'est davantage concentrée dans moins de sites sur les deux îles, probablement en raison de la perte d'habitat, qui, en combinaison avec d'autres perturbations d'origine anthropique, peut réduire la résilience de la population aux ouragans. Les taux de variation des populations avant à après la reproduction laisse penser qu'il existe un petit nombre de couples reproducteurs sur les deux îles. Par conséquent, compte tenu de nos résultats et en adoptant les catégories de l'IUCN, nous recommandons de classer *A. l. caymanensis* comme Vulnérable et *A. l. hesternana* comme En danger.

**Mots clés** *Amazona leucocephala caymanensis*, *Amazona leucocephala hesternana*, distance sampling, état de conservation

Parrots tend to have low reproductive rates and long life expectancies (Forshaw 2010). As a result of these life-history characteristics, most parrots living on islands are at high risk of extinction (e.g., Beissinger et al. 2008). Two subspecies of Cuban Parrot (*Amazona leucocephala*; hereafter Grand Cayman Parrot and Cayman Brac Parrot [for singular] or Cayman Islands Parrots [for plural]) inhabit the Cayman Islands—the Grand Cayman Parrot (*A. l. caymanensis*; Fig. 1A) and the Cayman Brac Parrot (*A. l. hesternana*; Fig. 1B). These parrots represent distinct conservation units (Russello et al. 2010 and literature therein) threatened by multiple factors (Wiley et al. 2004), including habitat loss due to forest clearing for urban development and agriculture; catastrophic natural events, such as Hurricane Ivan on Grand Cayman in 2004 and Hurricane Paloma on Cayman Brac in 2008; illegal hunting by farmers in agricultural areas; and the collection of nestlings for the pet trade.

The Cuban Parrot taxon is classified as Near Threatened by the International Union for Conservation of Nature (IUCN 2001). However, range-wide population estimates are lacking (but see Rivera-Milán et al. 2005, Stahala 2005), and the conservation status of the taxon has not been assessed at the subspecies level. We used before-after reproduction distance sampling surveys (Buckland et al. 2001, 2008, Marques et al. 2007) to assess the conservation status of parrots in the Cayman Islands.

Abundance estimates, corrected for changes in detection probability, are needed to monitor population dynamics, establish population-based conservation objectives, and assess conservation status (Rivera-Milán et al. 2005, 2014, 2015, 2016). Here, we focus on conventional and multiple-covariate distance sampling methods to estimate density (i.e., number of parrots per unit area) and population size (i.e., number of parrots in the survey region), accounting for the effects of detection covariates (e.g., time of day, point location, and parrot cluster size).

## Methods

We sampled 165 points in a survey region covering 15,550 ha on Grand Cayman (Fig. 2A) and 94 points in 3,527 ha on Cayman Brac (Fig. 2B). We excluded habitats considered unsuitable for parrots (e.g., bare ground and water bodies), or that were inaccessible for sampling (e.g., central mangrove swamp; Fig. 2A). The vegetation included plants typical of coastal and interior dry forests, shrublands, and wetlands; for example, red birch (*Bur-*

*sera simaruba*), silver thatch (*Coccothrinax proctorii*), cedar tree (*Cedrela odorata*), sea grape (*Coccoloba uvifera*), and buttonwood (*Conocarpus erectus*); as well as plants typical of degraded



**Fig. 1.** Grand Cayman (A) and Cayman Brac (B) Parrots can be detected as singles, in pairs, or in clusters of variable sizes. Photographs taken by Stuart Mailer, National Trust for the Cayman Islands.

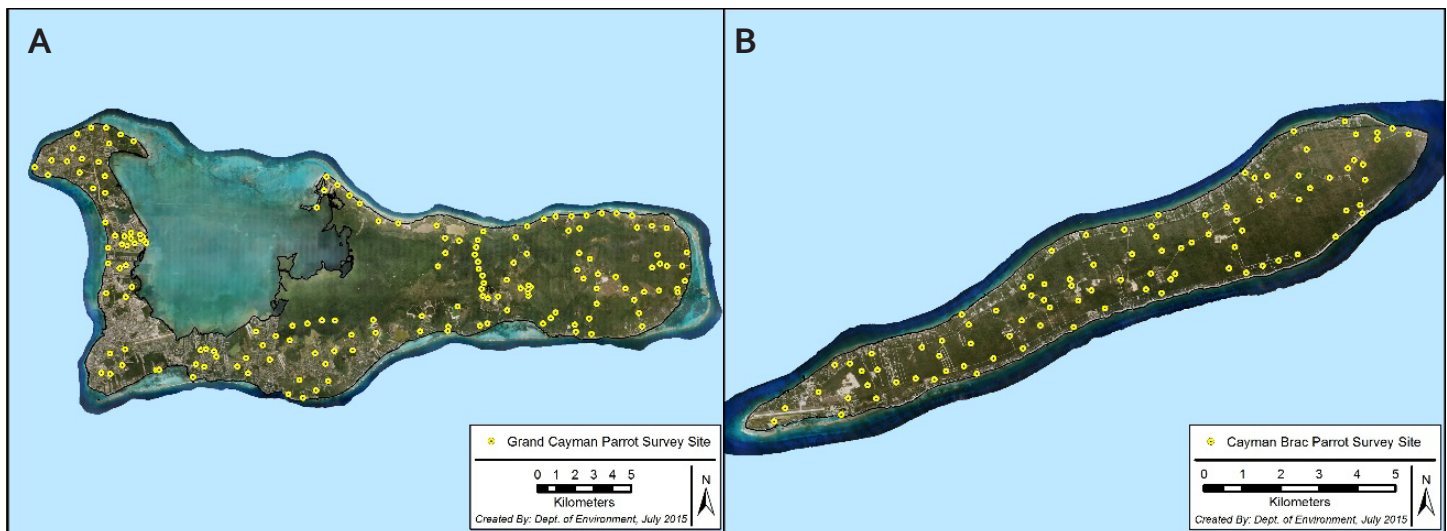


Fig. 2. Maps showing Grand Cayman (A) and Cayman Brac (B) survey points ( $k = 165$  and  $94$ , respectively).

habitats, such as wild tamarind (*Leucaena leucocephala*) and logwood (*Haematoxylum campechianum*); and mango (*Mangifera indica*) among other plants bearing fruits in agricultural areas. For additional information about the topography and vegetation of the Cayman Islands, see Brunt and Davies (1994) and Proctor (2012).

A team of two observers surveyed all points, with one observer mainly measuring detection distances, and the other observer mainly recording the data. The observers remained side by side for 6 min, measuring distances from each point to parrots detected singly or the geometric center of parrot clusters. A cluster was defined as two or more parrots  $\leq 10$  m from each other, showing similar behavior. A 6-min count increased the chance of detecting calling parrots visually, facilitating distance measurements with laser rangefinders. However, when calling parrots were not seen, we measured detection distances horizontally to the nearest locations (e.g., tree trunks), and used the following distance categories: 0–15, 16–30, 31–45, 46–60, 61–90, 91–120, 121–180, 181–240, 241–340, and 341–440 m (Rivera-Milán et al. 2005). Moving parrots were not included in density estimates, unless their initial locations were ascertained during or after the count. The points were visited in the morning and afternoon to increase detection probability. Survey effort accounted for the number of times a point was visited (Buckland et al. 2001).

We modeled detection as a function of distance and other covariates represented by vector  $\mathbf{z}$  (i.e.,  $g[r, \mathbf{z}]$ ; Marques et al. 2007). Density was estimated using

$$\hat{D} = \frac{n\bar{s}}{2\delta k\hat{P}(\mathbf{z}_i)}$$

Where  $\hat{D}$  is the number of parrots per hectare;  $n$  is the number of single and cluster detections;  $\bar{s}$  is the sample mean, which is used as an estimator of average cluster size when cluster detection is not size-biased; and  $k$  is the number of survey points. We estimated population size by extrapolating estimated density to the survey region of each island ( $\hat{N} = \hat{D} \times A$ ). Population rate of change before-after reproduction was estimated as  $\hat{R}_t = \hat{N}_{t+1} / \hat{N}_t$ .

After data truncation ( $w = 240$  m), we estimated detection given availability using

$$\hat{P}_{da}(\mathbf{z}_i) = \frac{2}{w^2} \int_0^w r\hat{g}(r, \mathbf{z}_i) dr.$$

Large clusters of parrots can be detected at longer distances than small ones (i.e., cluster detection may be size-biased). When cluster detection was size-biased ( $\alpha < 0.15$  which is the default value used in program Distance; Thomas et al. 2010),  $\log(s_i)$  was regressed on  $\hat{g}(r_i)$  to estimate the value of expected cluster size [ $\hat{E}(s)$ ] where  $\hat{g}(r_i) = 1$ , and  $\hat{E}(s)$  instead of  $\bar{s}$  was used to estimate density (Buckland et al. 2001).

We evaluated the fit of uniform, half-normal, and hazard-rate detection models with quantile-quantile plots and goodness-of-fit tests (Burnham et al. 2004). Model selection was based on minimization of Akaike Information Criterion ( $AIC_c$ ). Models with  $\Delta AIC_c < 2$  were considered to be equally supported by the data. Based on  $AIC_c$  and precision of the density estimator ( $CV < 0.20$ ), we selected the half-normal key function without series expansion for multiple-covariate analysis, which included the following variables: sampling period (1 = before reproduction, 2 = after reproduction), cluster size ( $\geq 2$  parrots), time of day (0630–1030, 1530–1830), detection time (1 = 0–3 min, 2 = 4–6 min), detection mode (1 = heard only, 2 = heard-seen or seen only), point location (1 = on road, 2 = off road), and land-cover type (1 = dry forest, 2 = dry shrubland, 3 = wetland, 4 = agriculture, and 5 = urban), as well as vegetation cover and disturbance level from conservation threats (1 = 0–50% [or none-medium disturbance], 2 = 51–100% [or medium-high disturbance]).

As an alternative to multiple-covariate analysis, we used the half-normal key function without series expansion and post-stratified the distance data by year or other factor covariates. We used the Z statistic to compare density estimates between years (Buckland et al. 2001). Because the Z test has low statistical power ( $1 - \beta$ ) and the density coefficient of variation (CV) usually is in the range of 0.10–0.30 for parrot distance sampling surveys (Rivera-Milán et al. 2005), we accepted statisti-

cal significance at  $\alpha < 0.15$  (Buckland *et al.* 2001, Thomas *et al.* 2010). Dispersion parameter was estimated as  $\hat{b} \sim n \times (CV[\hat{D}])^2$ . We expected parrot spatial distribution to be clumped ( $b > 1$ ) due to habitat loss and fragmentation from urban development and agriculture. For data analysis, we used program DISTANCE, Version 6.0, Release 2 (Thomas *et al.* 2010). We provide details of the most recent survey results before and after reproduction on Grand Cayman in 2014 and Cayman Brac in 2015. Results are means  $\pm$  bootstrap standard errors, with 95% confidence intervals in parentheses.

## Results

### Grand Cayman Parrot

The half-normal key function with no adjustment term and detection mode as a covariate provided the best fit to the distance data (e.g., Kolmogorov-Smirnov test:  $D_n = 0.10$ ,  $p = 0.25$ ). Detection mode was the most important covariate in the model set ( $AIC_c = 1,074.96$ ), followed by cluster size ( $\Delta AIC_c = 2.62$ ), and vegetation cover ( $\Delta AIC_c = 3.08$ ). Other covariates received negligible support from the data ( $\Delta AIC_c > 4.29$ ). Detection probability was  $0.260 \pm 0.025$  (0.216, 0.314) for parrots heard only and  $0.178 \pm 0.015$  (0.150, 0.210) for parrots heard-seen or seen only (Fig. 3A).

Estimated density (parrots  $ha^{-1}$ ) increased from  $0.172 \pm 0.026$  (0.128, 0.210) in August 2005 to  $0.411 \pm 0.077$  (0.279, 0.578) in August 2014 ( $Z = -2.94$ ,  $p = 0.002$ ). Extrapolation of these density estimates resulted in  $2,675 \pm 406$  (1,990, 3,263) and  $6,395 \pm 1,202$  (4,340, 8,987) parrots in the survey region after reproduction in August 2005 and 2014, respectively. Estimated density was  $0.363 \pm 0.067$  (0.238, 0.500) and population size was  $5,645 \pm 1,042$  (3,701, 7,775) parrots before reproduction in March 2014. Population rate of change ( $\hat{R} = \hat{N}_{t+1} / \hat{N}_t = 6,395 / 5,645$ ) before-after reproduction was 1.133 (~13%) in 2014. As expected, parrot spatial distribution was clumped ( $b > 1$ ) with the estimate of dispersion parameter increasing from 1.684 in August 2005 to 6.069 in August 2014.

### Cayman Brac Parrot

The half-normal key function with no adjustment term and sampling period as a covariate provided the best fit to the distance data (e.g., Kolmogorov-Smirnov test:  $D_n = 0.11$ ,  $p = 0.15$ ). Sampling period was the most important covariate in the model set ( $AIC_c = 2,157.51$ ), followed by detection time ( $\Delta AIC_c = 2.82$ ), and cluster size ( $\Delta AIC_c = 3.18$ ). Other covariates received negligible support from the data ( $\Delta AIC_c > 3.69$ ). Detection probability was  $0.145 \pm 0.014$  (0.119, 0.176) before reproduction and  $0.189 \pm 0.022$  (0.151, 0.237) after reproduction (Fig. 3B).

Estimated density (parrots  $ha^{-1}$ ) increased from  $0.160 \pm 0.021$  (0.116, 0.222) in July 2008 to  $0.219 \pm 0.028$  (0.171, 0.280) in July 2015 ( $Z = -1.69$ ,  $p = 0.09$ ). Extrapolation of these density estimates resulted in  $565 \pm 75$  (409, 782) and  $772 \pm 97$  (603, 989) parrots in the survey region after reproduction in July 2008 and 2015, respectively. Estimated density was  $0.178 \pm 0.018$  (0.146, 0.218) and population size was  $629 \pm 63$  (515, 769) parrots before reproduction in March 2015. Population rate of change before-after reproduction ( $\hat{R} = \hat{N}_{t+1} / \hat{N}_t = 772 / 629$ ) was 1.227 (or ~23%) in 2015. The estimate of dispersion parameter increased from 1.114 in July 2008 to 3.142 in July 2015.

## Discussion

We conducted before-after reproduction distance sampling surveys to estimate abundance, corrected for changes in detection probability. We used the abundance estimates derived from these surveys to assess the conservation status of Grand Cayman and Cayman Brac Parrots. Previous researchers assumed perfect detection of parrot singles and clusters (i.e., census or complete count; Bradley 1986, Wiley 1991, Wiley *et al.* 1991), and probably underestimated abundance on both islands (Buckland *et al.* 2001, 2008, Rivera-Milán *et al.* 2005, Marques *et al.* 2007).

Detection mode on Grand Cayman and sampling period on Cayman Brac were the most important detection covariates influencing abundance estimation. However, none of the covariates examined caused major heterogeneity in the detec-

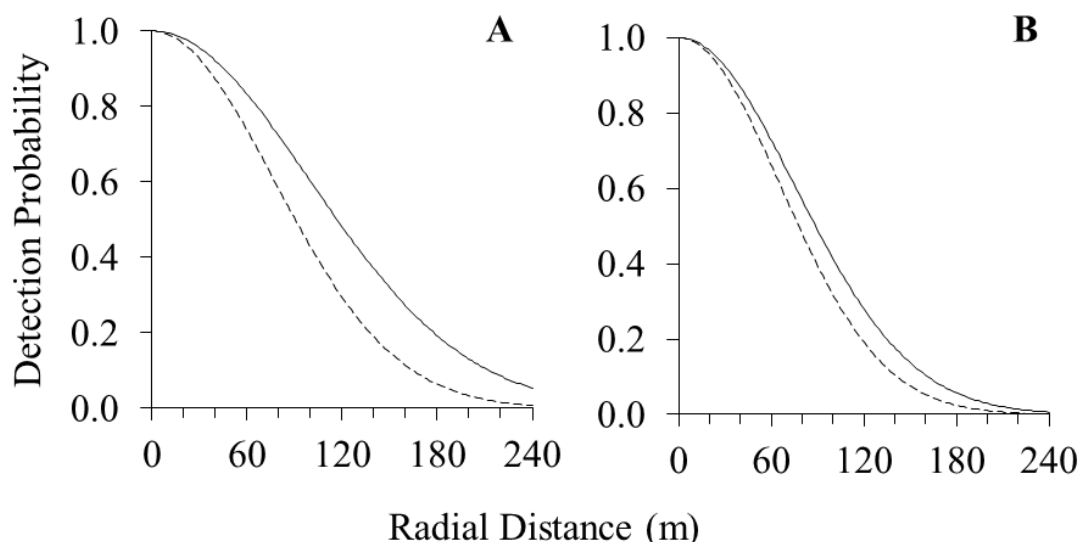


Fig. 3. Detection probability of (A) Grand Cayman Parrot heard only (solid line) and heard-seen or seen only (dashed line), and (B) Cayman Brac Parrot before (dashed line) and after reproduction (solid line).

tion functions (e.g., see Fig. 3 in Marques et al. 2007). The basic assumptions of distance sampling were met by survey design (systematic sampling) and two-observer teams (Buckland et al. 2001, 2008, Rivera-Milán et al. 2005, 2014, 2015, 2016). Moreover, conventional and multiple-covariate distance sampling generated similar abundance estimates, suggesting that model selection was of secondary importance for abundance inferences from the sampled points to the survey regions of both islands (Buckland et al. 2001).

Abundance estimates of Grand Cayman and Cayman Brac Parrots increased over time, despite the effects of natural and anthropogenic disturbances. However, parrot distribution became more clumped probably as a result of habitat loss, which in combination with other anthropogenic disturbances can decrease population resiliency to hurricanes (Wiley and Wunderle 1993, Beissinger et al. 2008). Moreover, population rate of change before-after reproduction suggested a small number of breeding pairs on both islands, which is a common characteristic of parrot populations (Renton and Salinas-Melgoza 2004, Stahala 2005, Forshaw 2010). Therefore, based on our results, we recommend classifying the Grand Cayman Parrot as Vulnerable (i.e.,  $N < 10,000$  but endemic and at medium-high risk of declining from natural and anthropogenic environmental disturbances) and the Cayman Brac Parrot as Endangered (i.e.,  $N < 1,000$  but endemic and at high risk of declining from natural and anthropogenic environmental disturbances) (e.g., Reed and Hobbs 2004, Traill et al. 2010).

Before-after reproduction surveys are conducted on each island every 2 yr (e.g., Grand Cayman Parrot in March and August 2016 and Cayman Brac Parrot in March and August 2017). Long-term monitoring will be used for modeling population dynamics, informing management decisions, and evaluating the results of actions taken to conserve parrots and their habitats in the Cayman Islands. Our survey design and count methodology are applicable to other bird populations of conservation concern in the Caribbean; and we suggest implementing them to assess population status, monitor population trends, and model population dynamics (Rivera-Milán et al. 2005, 2015, 2016, Rivera-Milán and Simal 2012).

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