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Density and Population Size of Yellow-shouldered Parrots (*Amazona barbadensis rothschildi*) and Brown-throated Parakeets (*Aratinga pertinax xanthogenius*) on Bonaire, Netherland Antilles

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Introduction

In December 2009, we sampled 62 6-minute random-systematic counting points (k) to estimate the density and population size of yellow-shouldered parrots and brown-throated parakeets in a survey region (A) of 7,873 hectares, which covered the Washington-Slaagbai National Park and forest, suburban, and agricultural areas between Brasil, Karpata, Dos Pos, Rincón, and Fontein. In March 2010, we sampled 104 points, covering a survey region of 17,000 hectares that included forest, urban, suburban, and agricultural areas in northern, central, and southern Bonaire (Figure 1). This survey provided a representative sample of low, medium, and high density habitats occupied or potentially occupied for feeding, roosting, and nesting. We estimated population size ($\hat{N}$) by extrapolating density ($\hat{D}$ = number/unit area) to the area covered by the surveys, which was defined as the area from which points were randomly selected for sampling (i.e. $\hat{N}$ =

$\hat{D} \times A$). The timing of this second survey coincided with the period of the year in which parrots are starting to explore nesting areas but still are congregating in roosting areas (i.e., males and females of different ages and reproductive status were available for detection at counting points). Because the parrot and parakeet populations are closed to emigration and immigration, surveys before and after reproduction give an estimate of rate of change over time ($\hat{R}_t = \hat{D}_{t+1} / \hat{D}_t$ = births − deaths during the breeding season or deaths during the nonbreeding season).

All survey points were georeferenced for GIS mapping and modeling of abundance and density from spatially-replicated count data before and after the breeding season of 2010. In this report, however, we focus on density and population size estimates based on multiple-covariate distance sampling and removal sampling (i.e., time of first detection in 6 1-minute counts/point). For additional information about methods, see the previous report.

Results and Discussion

Distance sampling. We combined the count data of the December 2009 and March 2010 surveys for this analysis, resulting in k = 110 points and n = 119 detections of parrot singles and clusters and 237 detections of parakeet singles and clusters within a maximum radius of detection (r) = 440 meters. Survey effort (K) accounted for the number of visits/point. We truncated the distance data of parrots at w = 240 meters (n = 104) and the distance data of parakeets at w = 140 meters (n = 194). Effective detection radius was 117 meters for parrots (SE = 6, CV = 0.05, 95% CI = 107 to 129) and 67 meters for parakeets (SE = 2, CV = 0.03, 95% CI = 63 to 71). Parrot detection probability was 0.24 within 117 meters (SE = 0.02, CV = 0.09, 95% CI = 0.20 to 0.29) and parakeet detection probability was 0.23 within 67 meters (SE = 0.02, CV = 0.07, 95% CI = 0.20 to 0.26). Detection probability was only about 0.07-0.13 for parrots and about 0.03-0.04 for parakeets within 440 meters from point centers (i.e., within survey area $a = \pi r^2 = 60.82$ hectares/point).

Parrot cluster detection was not size-biased ($r_{98} = -0.05$, $P = 0.33$). However, the detection of parakeet clusters was size-biased ($r_{192} = -0.25$, $P < 0.001$). The half-normal key function without adjustment term and with vegetation cover (0 = none, 1 = 1-25%, 2 = 26-50%, 3 = 51-75%, 4 = 76-100%) and time period (1 = 0-3 min, 2 = 3-6 min) as factor covariates fitted the count data of both species (Kolmorov-Smirnov and Cramer-von Mises family tests, all P values > 0.25; Figures 2 and 3). There was a strong interaction between parakeet cluster size and vegetation cover. Parakeet clusters were more detectable than singles in open and dense vegetation. Parrot counts showed a weaker interaction among these covariates, with clusters tending to be more detectable than singles in dense vegetation. Additionally, there was an interaction between time period and vegetation cover, with a tendency to make more detections of both species in dense vegetation during the second time period.

Detection models with other covariates did not receive strong support from the data (AIC or AICc > 2). For example, the detection probability of parrots was not influenced by the presence or absence (factor covariate) or the abundance (nonfactor covariate) of parakeets. Neither was detection probability affected by point location (1 = on road, 2 = off road), form of detection (1 = aural, 2 = visual), time of day (1 = 06:30-08:30 or 16:31-18:30, 2 = 08:31-10:30 or 15:30-16:30 hours; minutes after sunrise or minutes before sunset), and date (1 = December 2009, 2 = March 2010).

Average density was 0.17 parrots/hectare (SE = 0.03, CV = 0.16, 95% CI = 0.12 to 0.23) and 0.65 parakeets/hectare (SE = 0.05, CV = 0.08, 95% CI = 0.55 to 0.76), and average population size was 2,829 parrots (95% CI = 2,083 to 3,842) and 11,023 parakeets (95% CI = 9,432 to 12,881) in 17,000 hectares. Encounter rate (n/K) was the main component of parrot density variation (54%), followed by detection probability (36%), and cluster size (10%). Detection probability (67%) and cluster size (33%) were the main components of parakeet density variation. The spatial distribution of both species was clumped (dispersion parameter $\hat{b}$ = 1.22-2.5).

Removal sampling. The density of parrots at point level was strongly influenced by food abundance in forest, urban, suburban, and agricultural areas. Parrots were detected feeding the fruits and seeds of native and introduced plants at house backyards and small patches of vegetation in Rincón, Kralendijk, and other developed areas. The pods of mesquite (*Prosopis juliflora*) and other leguminous plants were an important food source during drought conditions between December 2009 and March 2010. There was no correlation between the counts/point of parakeets and parrot density/point, although both species co-occurred in many areas and were detected feeding basically on same plant species (Figure 4a).

The composite index of habitat suitability (food abundance index + food diversity index + habitat availability index − disturbance index) was a good predictor of parrot density/point (Figure 4b). Density ranged from 0.06 parrots/hectare at points with low habitat suitability (1) to 0.53 parrots/hectare at points with high habitat suitability (9). Average density was 0.17 parrots/hectare (SE = 0.03, CV = 0.17, 95% CI = 0.12 to 0.24) and average population size was 2,895 parrots (95% CI = 2,079 to 4,033) in 17,000 hectares.

Distance and removal sampling gave similar density estimates. The lower 95% confidence interval was 0.12 parrots/hectare or 2,079 parrots in 17,000 hectares, which still added over 1,000 individuals to the previous national abundance estimate based on roost counts. However, as a management target, we would like to keep density > 0.30 parrots/hectare (i.e., $\hat{N}$ > 5,000 parrots in 17,000 hectares) to secure the long-term viability of a parrot population that is at risk of extinction due to geographical isolation, climate change and the frequency of prolonged periods of dryness and food scarcity, as well as the poaching of nestlings and other human-induced disturbance (Traill et al. 2010, Pragmatic population viability targets in a rapidly changing world, Biological Conservation 143:28-34). With this management target in mind, we recommend the following:

1) Hiring and training new personnel at STINAPA Bonaire, Natural and Historic Resources Unit, to increase the efficiency and effectiveness of management-based monitoring and research.
2) Conducting a post-reproduction survey between September and November 2010 to estimate rate of change in the parrot and parakeet populations.
3) Using spatially-replicated count data to produce GIS maps of abundance and density before and after the breeding season.
4) Building a stochastic model to assess population viability in the face of uncertainty about climate change, rainfall and food abundance, and poaching of nestlings.

5) Integrating long-term monitoring and research to guide decision making and evaluate management actions inside and outside the Washington-Slaagbai National Park.

Figure 1. Map of Bonaire showing 185 points (*K*) from which a total of 110 points (*k*) were randomly chosen for sampling in December 2009 (*k* = 62) and March 2010 (*k* = 104). The survey region (*A*) covered 17,000 hectares, including the Washington-Slaagbai National Park, Brasil, Karpata, Rincón, Tolo, Colombia, Washikemba, Bakina, Lima, and Belnem.

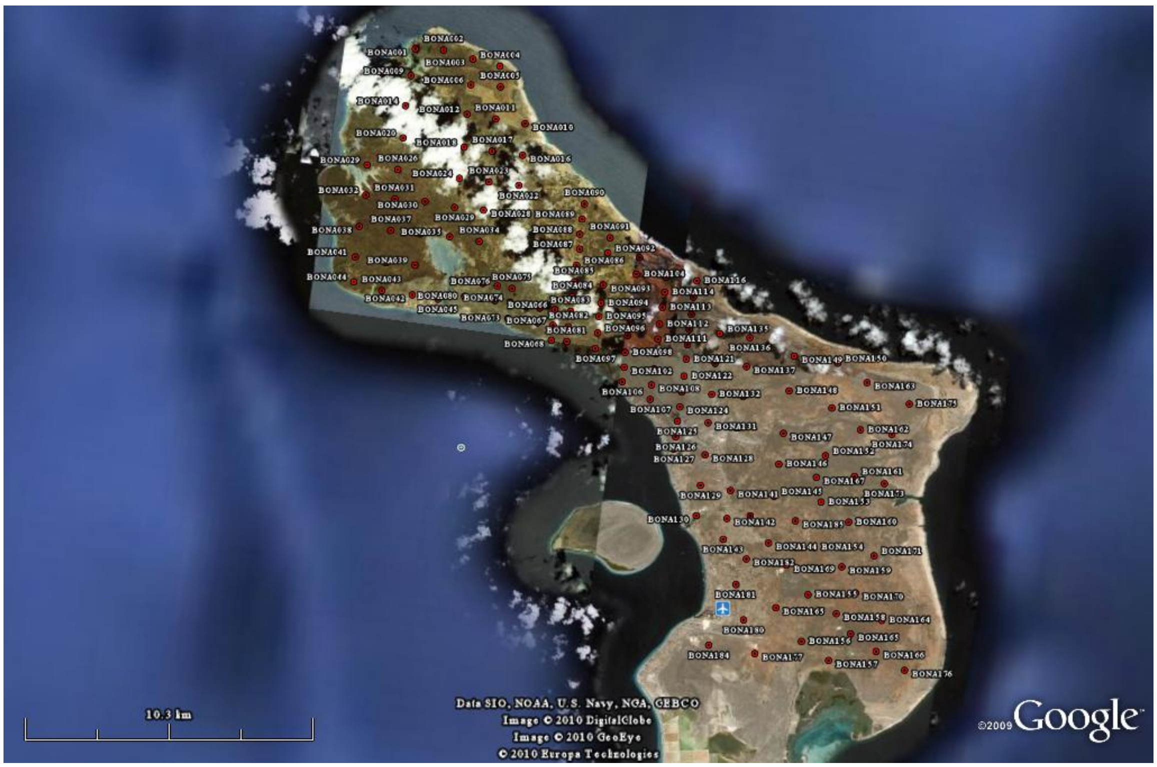

Figure 2. Quantile−quantile plot showing the fit of the half-normal key function without series expansions to the distance data of the yellow-shouldered parrot (A), and histograms of detection probability (B) and probability density function (C).

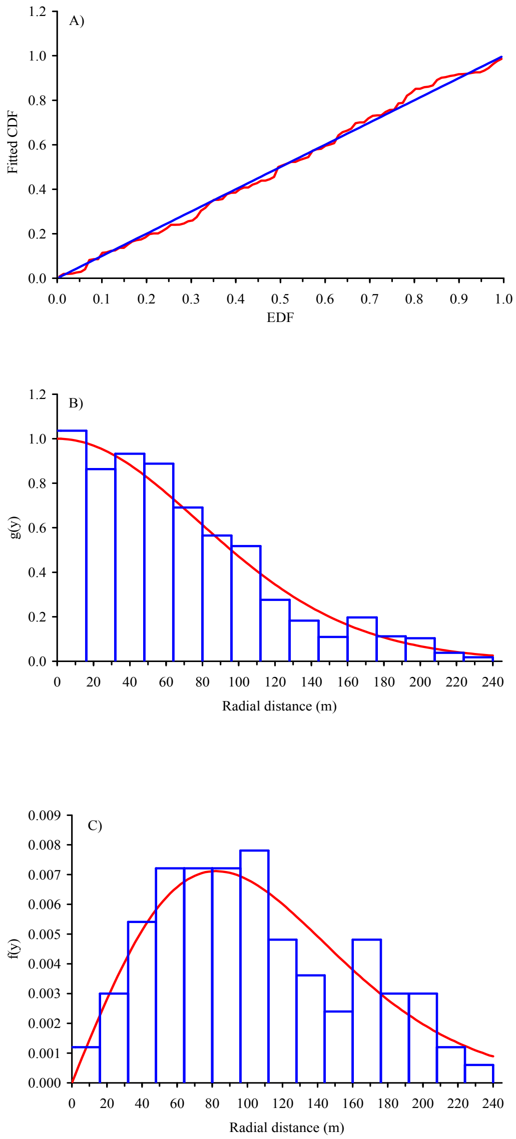

Figure 3. Quantile−quantile plot showing the fit of the half-normal key function without series expansions to the distance data of the brown-throated parakeet (A), and histograms of detection probability (B) and probability density function (C).

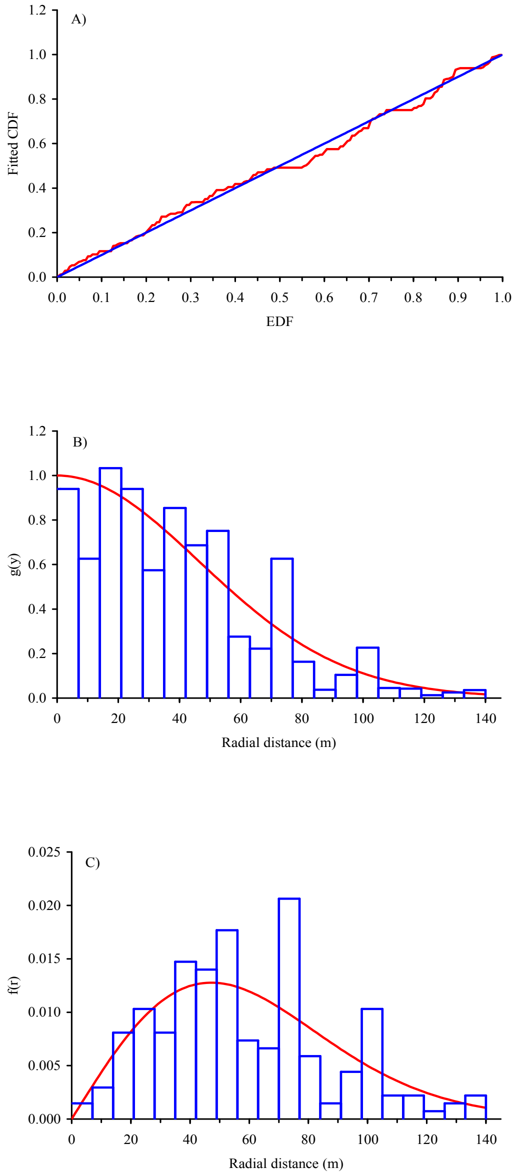

Figure 4. Counts/point of brown-throated parakeets and parrot density/point (A), and increase of parrot density/point as a function of habitat suitability index (B).