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Distance Sampling Surveys of Yellow-shouldered Parrots (*Amazona barbadensis rothschildi*) on Bonaire, Dutch Caribbean

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INTRODUCTION

Geographical isolation and small population size increase the risk of extinction of psittacids on islands (Beissinger et al. 2008). The island of Bonaire is outside the Caribbean hurricane belt, but annual and seasonal rainfall, fluctuations in food availability and abundance, intraspecific and interspecific competition for limited resources, hunting at farms, poaching of nestlings, avian and mammalian nest depredation, and habitat loss can affect the viability of the endemic Yellow-shouldered Parrot population (Birdlife International 2008, Martin 2009, Williams 2009, Parks 2010, Richards 2010). Therefore, the integration of research and monitoring should be a priority for local organizations responsible for the management and conservation of parrots and their habitats on Bonaire (Lindenmayer and Likens 2010).

We used a systematic sampling scheme with multiple random starts to survey parrots on Bonaire in March 2010 and 2012 (before reproduction) and October 2010 and

2011 (after reproduction). Our objectives were (1) to estimate density ($\hat{D}$), population size ($\hat{N}$), occupancy ($\hat{\psi}$), rate of change over time ($\hat{r}$), and an interaction factor ($\hat{\varphi}$) between Yellow-shouldered Parrots and Brown-throated Parakeets (*Aratinga pertinax xanthogenius*); (2) to establish population conservation objectives; and (3) make recommendations to integrate research and monitoring as part of the development of an adaptive management strategy (Runge 2011).

When estimating population size there are three basic options: (1) design a true census of areas and parrots (i.e., all areas are covered and all parrots/area are counted); (2) design a probabilistic survey (i.e., a sample of areas) in which parrot detection probability is perfect (i.e., a census or complete count of parrots at sampled areas); or (3) design a probabilistic survey in which parrot detection probability is estimated from incomplete count data (i.e., two-stage survey sampling design; Thompson et al. 1998, Buckland et al. 2008). Because the first two options are not possible for psittacids on Bonaire, we designed a survey sampling scheme and combined count methods (conventional, multiple-covariate, and hierarchical distance sampling, count-removal and repeated-count sampling) to account for survey and site specific covariates that may affect detection and density estimation at point level and across points. In this report we concentrate on conventional and multiple-covariate distance sampling and count data generated from islandwide surveys before and after parrot reproduction.

Many methods are available for the analysis of count data with imperfect detection (for a recent review, see Nichols et al. 2009). However, distance sampling offers a flexible theoretical framework for parameter estimation and modeling, and details about method development and application, when the count unit is a point, have been given in many publications (Buckland et al. 2001, 2004, 2008; Buckland 2006; Marques et al. 2007; Thomas et al. 2010). In an effort to inform decisions about research and monitoring efforts, we present detailed information about survey sampling design and distance sampling methodology. In Appendix 1, we also provide a detailed review of P. Saunders (2011) master thesis.

STUDY AREA AND METHODS

Survey Design

We used a 1-km^2 (100 ha) sampling grid to establish 188 points in a random-systematic manner (Fig. 1). Neighboring points were separated by a minimum distance of 400–500 m in rugged terrain and dense vegetation (e.g., Brasil, Karpata, and Tolo). Points were separated by 500–1,000 m in the Washington-Slagbaai National Park and 500–1,600 m in farmland and urban areas of northern, central, and southern Bonaire (Fig. 1). A systematic procedure (*n*-in-*k* design) simplified sampling unit selection across the sampling frame (Schaeffer et al. 1990, Thompson et al. 1998). To secure adequate randomization and replication, we selected a random start every 10 points (i.e., 1-in-10 systematic sampling design). Parrots are distributed across the landscape in some stochastic manner (i.e., random, regular, or clumped) with rate parameter *D* (expected number/unit area). To justify a statistical inference from the sample (parrots in survey area *a*) to the population of interest (parrots in survey region *A*) using design-based distance sampling methods it is critical that sampling units (points) are random with respect to the spatial distribution of parrots (Buckland et al. 2001, 2004, 2008; Thomas et al. 2010).

Our survey sampling scheme provided representative coverage of low, medium, and high density habitats that were occupied or potentially occupied by parrots in a survey region (A) covering 17,000 ha, excluding waterbodies and bareground areas with little or no vegetation for feeding, roosting, or nesting (Fig. 1). Population size was estimated by extrapolating estimated density to the survey region (i.e. $\hat{N}_t = \hat{D}_t \times A$). Because the parrot population is closed to emigration and immigration, we used the survey data to estimate rate of change over time (e.g., births – deaths between March and October 2010, and deaths between October 2010 and March 2011).

Distance Sampling

Conventional distance sampling is based on estimation of a detection function, $\hat{g}(r)$ in the case of point transects, which decreases with distance (r) and is needed to estimate detection probability ($\hat{P}$). By definition, $g(r)$ is the conditional probability of detecting a single individual or cluster of individuals, given radial distance (r) from the center of a random point (i.e., $P_{d|r}$). Detection probability may be influenced by multiple factors associated with the species, environment, and observer. For this reason, we modeled detection as a function of distance (r) and covariates represented by vector $\mathbf{z}$ (i.e., $g[r, \mathbf{z}]$; Marques and Buckland 2004, Marques et al. 2007).

Density was estimated as

$$\hat{D} = n\,\hat{h}\,(0|\mathbf{z}_i)\,\bar{s}\,/2\pi k$$

where $\hat{D}$ is the number of parrots/ha; n is the number of single and cluster detections; $\hat{h}$ $(0|\mathbf{z}_i)$ is the slope of the estimated probability density function of radial distances $\hat{f}\,(r)$, evaluated at r = 0, and for which covariates $\mathbf{z}_i$ were recorded; $\bar{s}$ is the sample mean, which was used as an unbiased estimator of average cluster size, when cluster detection was not size biased; and *k* is the number of surveyed points in the survey region.

For conventional distance sampling, we used the cluster size-bias regression method (Buckland et al. 2001). Cluster size was included as a covariate in multiple-covariate distance sampling models (Marques and Buckland 2004, Marques et al. 2007).

Detection probability was estimated as

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

and effective radius of detection as

$$\hat{p} = \sqrt{2/\hat{h}(0\,|\,\mathbf{z}_i)} \text{ or } w\times\sqrt{\hat{P}_a(\mathbf{z}_i)}$$

after data truncation at distance w = 240 m.

The same two-observer team surveyed all points, with one observer recording the data and the other measuring detection distances. Both observers remained side by side, recording the time of first detection during six 1-min count intervals and measuring radial distances to calling and noncalling parrots detected singly or the geometric center of clusters. A cluster was defined as two or more parrots within 10 m of each other, showing similar behavior.

A 6-min count increased the chance of making visual contact with calling parrots (Rivera-Milán et al. 2005). However, when calling parrots were not seen, we measured distance to the nearest horizontal location (Burnham et al. 2004) and used 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). The use of rangefinders and distance categories reduced distance measurement errors, because in most instances we were able to approximate the location of calling parrots. We did not include moving parrots in density estimates, unless their initial locations were ascertained during or immediately after the 6-min count. We spent 1–5 min after the 6-min count double-checking that detection distances and ancillary data were recorded correctly. The purpose of having a two-observer team was to increase the chance of meeting method assumptions (i.e., detecting parrots at point centers; determining their initial locations before movement; estimating cluster sizes accurately; and measuring distances exactly or at least allocating singles and clusters to correct distance categories; Buckland et al. 2001, 2008; Buckland 2006, Burnham et al. 2004). We did not implement any form of the double-observer method (Nichols et al. 2009), but the count data were also analyzed using hierarchical distance sampling, count-removal sampling, and repeated-count sampling (Royle et al. 2004, Royle and Dorazio 2008; F. F. Rivera-Milán and F. Simal, ongoing data collection and analysis).

We truncated the distance data to reduce cluster size-bias effect, remove outliers, and improve the fit of detection models. After data truncation, we evaluated the fit of detection models (uniform, half-normal, and hazard-rate key functions with and without cosine and polynomial adjustment terms) with quantile-quantile plots and goodness-of-fit tests (Burnham et al. 2004, Thomas et al. 2010). Model selection was based on minimization of Akaike Information Criterion (AIC or $\mathrm{AIC_c}$; Buckland et al. 2001). Models with differences in AIC or $\mathrm{AIC_c} < 2$ were considered to be equally supported by the data. We used nonparametric bootstrapping (resamples $B = 999$) for robust estimation of standard errors and 95% confidence intervals, and accounted for model selection uncertainty through model averaging (Buckland et al. 2001).

The half-normal and hazard-rate key functions with and without cosine or simple polynomial adjustment terms were used to explore the effects of covariates on detection probability. We defined factor covariates as: (1) sampling period (SP, 1 = March 2010, 2 = October 2010, 3 = October 2011, 4 = March 2012); (2) time of day (TD, 1 = 06:30–09:00 and 16:30–18:30 hrs, 2 = 09:01–10:30 and 15:30–16:29 hrs); (3) point location (PL, 1 = on road, 2 = off road [i.e., ≥ 200 m from nearest road]); (4) detection form (DF1, 1 = heard only [i.e., no visual contact], 2 = heard-seen or seen only [visual contact]; or DF2, 1 = heard [visual or no visual contact], 2 = seen only; Marques et al. 2007); (5) detection time (DT, 1 = 0–3 min, 2 = 4–6 min [i.e., 2 3-min "snapshot" counts; Buckland 2006]); (6) vegetation cover (VC, 1 = 0–50%, 2 = 51–100%); (7) parakeet presence (PP, 0 = not detected, 1 = detected); (8) caracara presence (CP, 0 = not detected, 1 = detected); and (9) habitat type (HT1, 1 = dry forest, 2 = dry scrub, 3 = mixed forest-scrub, 3 = urban with mixed vegetation, 4 = agriculture with mixed vegetation; or HT2, 1 = lower terrace, 2 = middle terrace, 3 = higher terrace, 4 = escarpment, and 5 = undulating, following the landscape classification of De Freitas et al. 2005). Detection angle (10–360°) and cluster size (≥ 2 parrots) were defined as continuous covariates. Time of day was also treated as a continuous covariate (Marques et al. 2007).

Using information theory, we analyzed the parrot distance data with a common detection function for all sampling periods (SP) and habitat types (HT1 or HT2), with different detection functions for each sampling period and habitat type through stratification (spatial scale) or poststratification (temporal scale), and with a common detection function and sampling period and habitat type as factor covariates (Buckland et al. 2001; 2004; Alldredge et al. 2007; Marques et al. 2007). Survey effort accounted for the number of visits/point (i.e., v = 1–4 visits to k = 157 points). Distance sampling is pooling robust, meaning that not accounting for covariates other than distance (r) would not bias overall density estimation unless detection heterogeneity is extreme (see, e.g., Marques et al. 2007: fig. 3). Program Distance 6.0, Release 2, was used for the analysis of distance sampling data (Thomas et al. 2010).

Exploratory Data Analysis, Statistical Tests, and N-mixture Model

Exploratory data analysis and statistical tests were conducted outside program Distance (e.g., unpaired t test, hypothesized difference = 0 for factor covariate point location, implying equal detection of parrots along and away from roads; or one-way ANOVA for habitat type, hypothesized difference = 0, implying equal detection of parrots in dry forest, dry scrub, mixed forest-scrub, urban with mixed vegetation, and agriculture with mixed vegetation, or the landscape categories of De Freitas et al. 2005). Exploratory data analysis and statistical tests complemented model selection and inference based on information theory (e.g., the inclusion of point location and habitat type as factor covariates in detection models not receiving empirical support from the distance data).

We used time-series diagnostic tools (e.g., autocorrelation function, ACF) to determine the periodicity of dry and wet years with rainfall data collected by the Meteorological Department of Curacao at Bonaire′s Flamingo Airport Station in 1971–2011. In dry ecosystems, rainfall can correlate with food abundance, which in turn can influence rate of change over time (i.e., $R_t = D_{t+1}/D_t = N_{t+1}/N_t = \psi_{t+1}/\psi_t$ = births –

deaths). Rate of change over time is an integrated parameter that should be estimated using before-and-after reproduction survey data to test general hypotheses about population dynamics (e.g., births > deaths in above-average rainfall years).

Developing a set of models associated with hypotheses about factors driving the dynamics of the parrot population is an important component of adaptive management (Nichols and Williams 2006, Runge 2011, Johnson et al. 2011, Rivera-Milán et al. 2012). With this in mind, we built a Poisson-binomial mixture model within a Bayesian analysis framework to explore the relationship between parrot abundance (λ) and habitat suitability at surveyed points (Royle and Dorazio 2008, Kéry and Schaub 2012). Habitat suitability index (HSI) represented a composite covariate equaling the sum of indices of food abundance (0 = none, 1 = low, 2 = medium, 3 = high), food diversity (0 = none, 1 = 1–2 plant species, 2 = 3–4 plant species, 3 = more than 4 plant species bearing fruits), and habitat availability (0 = none, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, 4 = 76–100%), minus disturbance level (0 = none, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, 4 = 76–100% based on threats, such as urban development, invasive plants and animals, vegetation damage, and the presence of potential predators within 200 m of point centers). Details of this type of models will be given in future reports and publications (F. F. Rivera-Milán and F. Simal, ongoing data collection and analyses).

RESULTS AND DISCUSSION

We made 229 detections of parrot singles and clusters (n) in 157 points (k) surveyed 1–4 times (v) in March 2010–2012 and October 2010–2011; 58 of these detections were of parrots heard only (no visual contact) and 171 detections were of parrots heard-seen or seen only (visual contact). Average cluster size (s) was 2.2 (SE =

0.081), expected cluster size was 2.1 (SE = 0.098), and there was a slight tendency to detect large clusters (s = 5–10) at longer distances than small clusters (size-bias regression method: $r = -0.081$, df = 220, $P = 0.128$).

The histogram of detection distances had a median of 105 m with a minimum distance of 10 m and a maximum distance of 403 m (Fig. 2). This histogram is considered typical of unadjusted point-count survey data, with detections initially increasing (0–128 m) and then decreasing as parrots become less detectable with increasing distance from point centers (128–403 m). Detection time (DT, 1 = 0–3 min, 2 = 4–6 min) was the only covariate showing statistical significance (mean difference = –46.606, $P < 0.001$), with a tendency to detect distant parrots during the second part of the 6-min count (Fig. 3).

In conformity with exploratory data analysis and statistical tests (Fig. 3), detection time was the most important covariate influencing the detection probability of parrots (Table 1 and Fig. 4). The half-normal key function without adjustment term and detection time as a covariate provided the best fit to the distance data (Table 1). The inclusion of detection time in detection models was consistently supported by the distance data collected in four sampling periods. Density estimates were similar but precision was gained by including detection time in the models (HN + 0[DT], $\hat{D}$ = 0.176 parrots/ha, CV $\hat{D}$ = 0.079; HN + 0, $\hat{D}$ = 0.172 parrots/ha, CV $\hat{D}$ = 0.085; Table 1). However, detection time did not cause extreme heterogeneity in the detection function, and therefore density estimates did not differ between the two 3-min counts (Fig. 5), which in essence represented consecutive "snapshots" as defined by Buckland (2006). Habitat type, sampling period, detection form, time of day, point location, cluster size and other factor and nonfactor covariates did not receive empirical support from the data (i.e., ΔAIC > 2; Table 1). Detection probability averaged 21% and effective radius of detection averaged 109 m (Table 2), which compared well with the median of detection distances of unadjusted counts (Fig. 2). Quantile-quantile plots and goodness-of-fit tests did not show major problems with the distance data (P values > 0.20), suggesting that the basic assumptions of distance sampling were generally met (Buckland et al. 2001, 2008; Burnham et al. 2004; Buckland 2006; Marques et al. 2007; Thomas et al. 2010), and that relatively unbiased density estimates were obtained for population monitoring and modeling (Thomas et al. 2004; Rivera-Milán et al. 2005, 2012).

In March 2010 (before reproduction), estimated density was 0.165 parrots/ha and population size was 2,810 parrots in 17,000 ha. In October 2010 (after reproduction), estimated density was 0.192 parrots/ha and population size was 3,322 parrots in 17,000. Estimated rate of change was 0.167 or 18% (i.e., births – deaths = 512 parrots before-and-after reproduction; Table 3). Estimated density and population size were similar in March 2010–2012 and October 2010–2011 (Tables 4 and 5). However, between October 2011 and March 2012, estimated rate of change was –0.182 or –17% (i.e., deaths = 545 parrots; Table 6).

Births and deaths balanced out in 2010–2012, which may be explained by fluctuations in food abundance and demographic rates during wet and dry seasons. Above-average rainfall occurred with a periodicity of about 5 years on Bonaire (e.g., 2006 was the second driest year and 2010 was the second wettest year on record; Figs. 6–8). Parrot abundance corrected for detection (average λ = 3.8) showed an upward curvilinear relationship with the index of habitat suitability (Fig. 9). The Poisson-binomial mixture model and distance sampling model generated similar parameter estimates (Tables 3 and 7, Fig. 9). The similarity of parameter estimates using different estimators and modeling frameworks is encouraging for mapping parrot occupancy and density gradients and studying population fluctuations and trends (Royle et al. 2004; Thomas et al. 2004; Rivera-Milán et al. 2005, 2012; McKenzie et al. 2006; Royle and Dorazio 2008).

Population conservation objectives are presented in Table 7. These population conservation objectives can serve as baselines to evaluate large-scale management actions. For example, as a result of management actions, we would like density to be above 0.163 parrots/ha, meaning more than 2,774 parrots in 17,000 ha (for a review of population viability targets, see Traill et al. 2010). This overall abundance would result in occupancy and encounter rate estimates greater than 42% at survey points. We also would like rate of change to be above 0.167, meaning that more than 500 parrots are added to the population before the dry season, which appears to be a period of high mortality, particularly for hatching-year parrots (see, e.g., Stahala 2005). Additionally, an interaction factor above 0.908 would be indicative of negligible negative interactions between parrots and parakeets; an interaction factor equaling 1 would be indicative of independent coexistence, and an interaction factor above 1 would be indicative of positive interactions (e.g., population increases in response to a similar or covarying resource in the environment; MacKenzie et al. 2006).

Method Assumptions

The basic assumptions of distance sampling are:

(1) *Parrot detection at zero distance is perfect*. To meet this assumption, two experienced observers remained side by side for 6 min. One observer measured detection distances, and the other recorded the data and helped with detection distances during and after the 6-min count. We spent 1–5 min after the 6-min count checking for parrots missed near point center (0–30 m) and taking care that detection distances and ancillary data were recorded correctly. Detections near point centers are the most important ones for density estimation (Buckland et al. 2001). We are confident that $g(0) = 1$, regardless of cluster size and other detection covariates.

(2) *Parrots are detected at initial locations before movement*. We recorded calling and noncalling parrots during two 3-min “snapshot” counts/point (Buckland 2006). We did not include in density estimates any moving parrot for which we could not determine initial location to the nearest meter or within a distance category (Rivera-Milán et al. 2005). Density estimates were similar for two 3-min counts/point (Fig. 5), providing evidence that parrot movement was negligible. Anyhow, parrot movement seemed to be away from point centers in most instances, which would result in density underestimation (Buckland et al. 2001).

(3) *Distances to parrot singles and clusters are measured without error*. We measured exact distances with rangefinders. However, when this was not possible (e.g., no visual contact with a parrot heard), we used rangefinders and

distance categories to relax method assumptions (i.e., the parrot heard was allocated to the correct distance category). The two-observer team usually had visual contact with calling parrots during 6-min counts. Therefore, we consider that exact distance measurements and distance category allocations did not bias density estimation.

(4) *Cluster size is measured without error*. We used the size-bias regression method (Buckland et al. 2001) and included cluster size as a covariate in detection models (Marques and Buckland 2004, Marques et al. 2007). As mentioned before, most aural detections were followed by visual contact with parrots, facilitating estimation of average cluster size. Moreover, cluster size was not an important source of detection heterogeneity (Table 1).

(5) *Survey points are representative of survey region*. The surveys provided representative coverage of low, medium, and high density habitats that were occupied or potentially occupied by parrots on Bonaire. Point location was independent of parrot spatial distribution. Therefore, this assumption was met by design using a systematic survey sampling scheme with multiple random starts (Scheaffer et al. 1990; Thompson et al. 1998; Buckland 2001, 2008).

RECOMMENDATIONS AND ADDITIONAL COMMENTS

(1) Parrot distribution was slightly clumped (range of estimate of dispersion parameter $\hat{b}$ = 1.3–1.5; Buckland et al. 2001). Therefore, we recommend sampling 150 points (k) in March and October (i.e., survey effort/point/year $K = k \times v = 150\times 2 = 300$) to continue estimating density with precision (CV $\hat{D}$ =

0.10–0.15). We needed about 8 days to sample 104 points in March 2010, 112 points in October 2010, 121 points in October 2011, and 124 points in March 2012 (range of CV $\hat{D}$ = 0.11–0.20). We have augmented the random-systematic sampling scheme (k = 373, A = 18,000 ha) and are planning to survey at least 150 points in October 2012 (Fig. 10).

(2) Continue combining count methods to estimate detection probability, density, population size, occupancy, rate of change over time, and the interaction factor between parrots and parakeets. Major motivations for the combination of count methods is the development of hierarchical distance sampling models with covariates affecting both detection and density at points, and the preparation of GIS maps showing occupancy and density gradients to target key habitats for management and conservation (Royle and Dorazio 2008, Kéry and Schaub 2012).

(3) Rainfall can be an important predictor of fluctuations in food abundance and changes in parrot density as a result of reproduction and survival rates (i.e., births = deaths, births < deaths, or births > deaths). Therefore, we recommend collecting rainfall and food abundance data as part of monitoring and research efforts to improve our understanding of the dynamics of the parrot population. A fruiting phenology study has been initiated with cacti and other plants of key importance for psittacids and other frugivores on Bonaire.

(4) We recommend collecting telemetry and nest-monitoring data (Stahala 2005, 2008; Williams 2009; Williams and Evans 2010) to study daily and seasonal movements, estimate home range and demographic parameters, and better

understand the mechanisms driving the dynamics of the parrot population. Decomposing rate of change into separate estimates of survival and recruitment is costly but can lead to tests of specific hypotheses (e.g., constant survival of breeding and nonbreeding adults, high productivity of breeding pairs, and high survival of hatching-year parrots during wet years). Long-term research and monitoring are essential for an adaptive management strategy (Rivera-Milán et al. 2005, 2012; Nichols and Williams 2006, Johnson et al. 2011, Runge 2011).

(5) Design large-scale management experiments, for example, combining different types of nest boxes with the creation and restoration of natural tree cavities to improve our understanding of the effects of density dependent factors on population rate of change, and determine if we can exert at least partial control over carrying capacity by establishing special management zones inside and outside the Washington-Slagbaai National Park. Monitoring is essential to gain scientific knowledge for conservation (Nichols and Williams 2006). However, care must be taken with the use of nest boxes, because we may increase the abundance of thrashers and bees at key nesting areas (Williams and Evans 2010).

(6) Remove and keep under control goats and other introduced mammals within special management zones. Given the potential importance of nest depredation and primary productivity, we consider this to be a priority for the conservation of parrots and their habitats. This management action should also be conducted experimentally (e.g., before-after-control-impact design; Stewart-Oaten et al. 1986)

(7) Poaching of nestlings continues to be a problem (Williams and Evans 2010), and an unknown number of parrots are killed annually at farms (Parks 2010). In an effort to inform decisions about future research and monitoring, we provide a detailed review of Saunders (2011) master thesis in Appendix 1.

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Figure 1. Random-systematic survey sampling scheme (k = 188 points) for a survey region (A) covering 17,000 ha in Bonaire

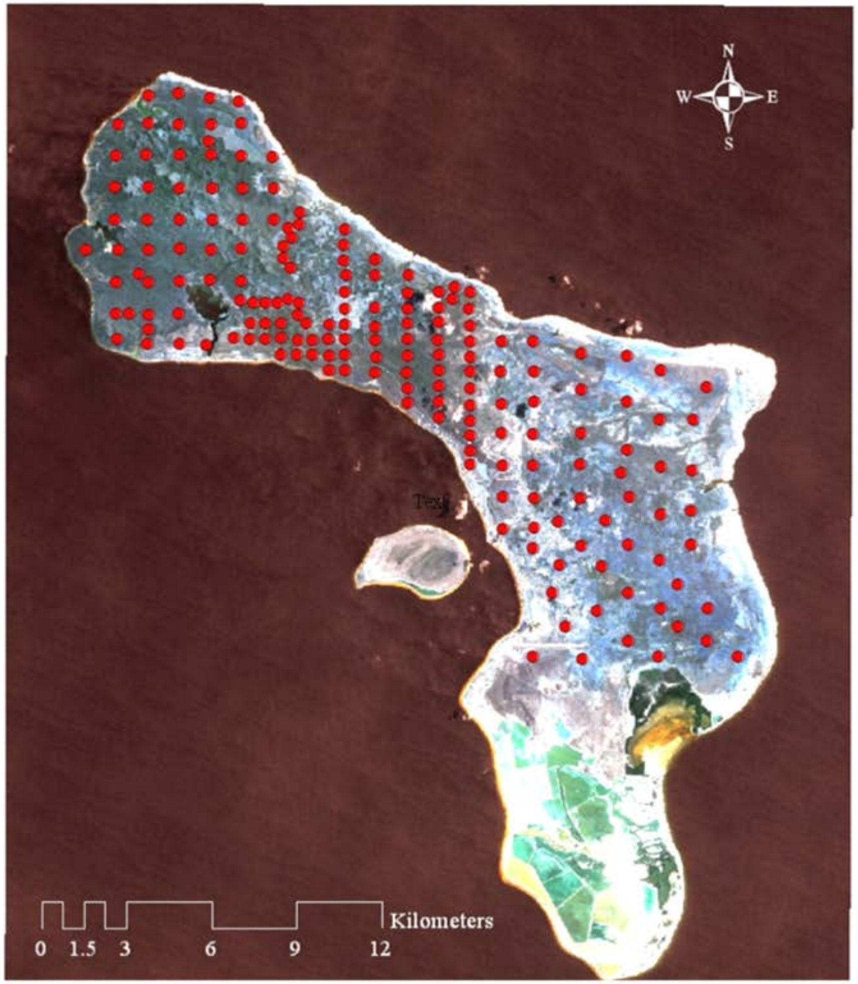


Figure 2. Descriptive statistics and frequency distribution of YSPA detections (*n* = 229) in March 2010–2012 and October 2010–2011

From (>=)	To (<)	Count
10.000	49.300	41
49.300	88.600	49
88.600	127.900	49
127.900	167.200	36
167.200	206.500	13
206.500	245.800	14
245.800	285.100	5
285.100	324.400	10
324.400	363.700	4
363.700	403.000	8
	Total	229

	Distance
Mean	128.633
Std. Dev.	91.380
Std. Error	6.039
Count	229
Minimum	10.000
Maximum	403.000
Variance	8350.330
Coef. Var.	0.710
Range	393.000
Median	105.000

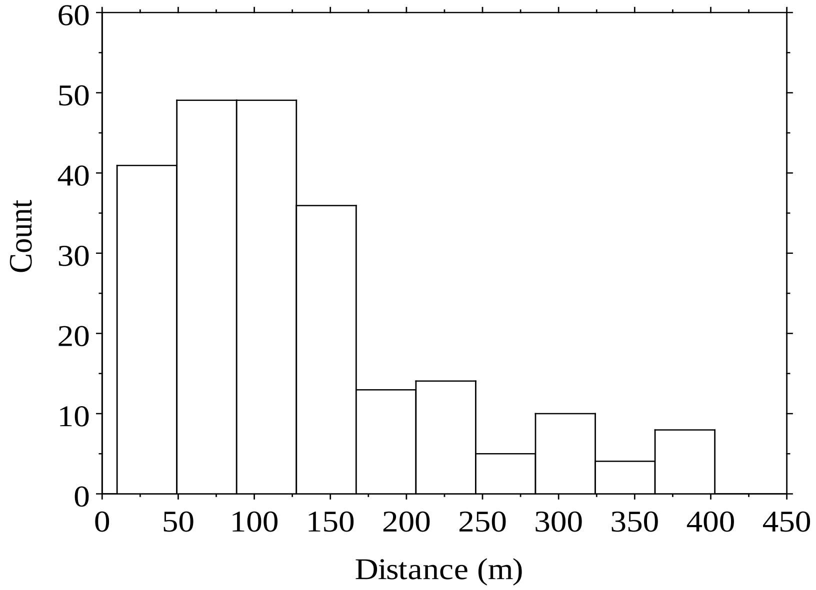


Figure 3. Box plot and unpaired *t* test of detection distance (0–440 m) vs. detection time (1 = 0–3, 2 = 4–6 min) based on YSPA survey data (*n* = 229) collected in March 2010–2012 and October 2010–2011

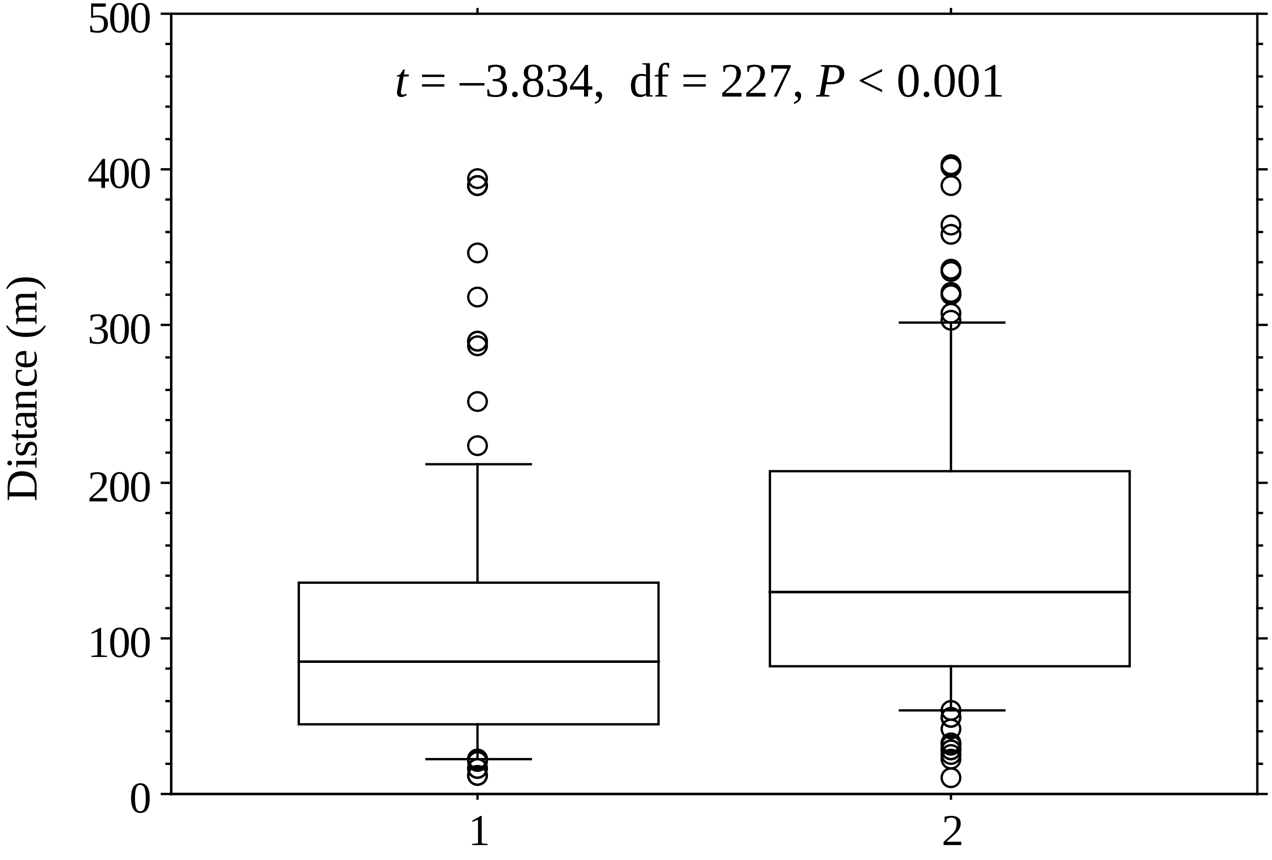
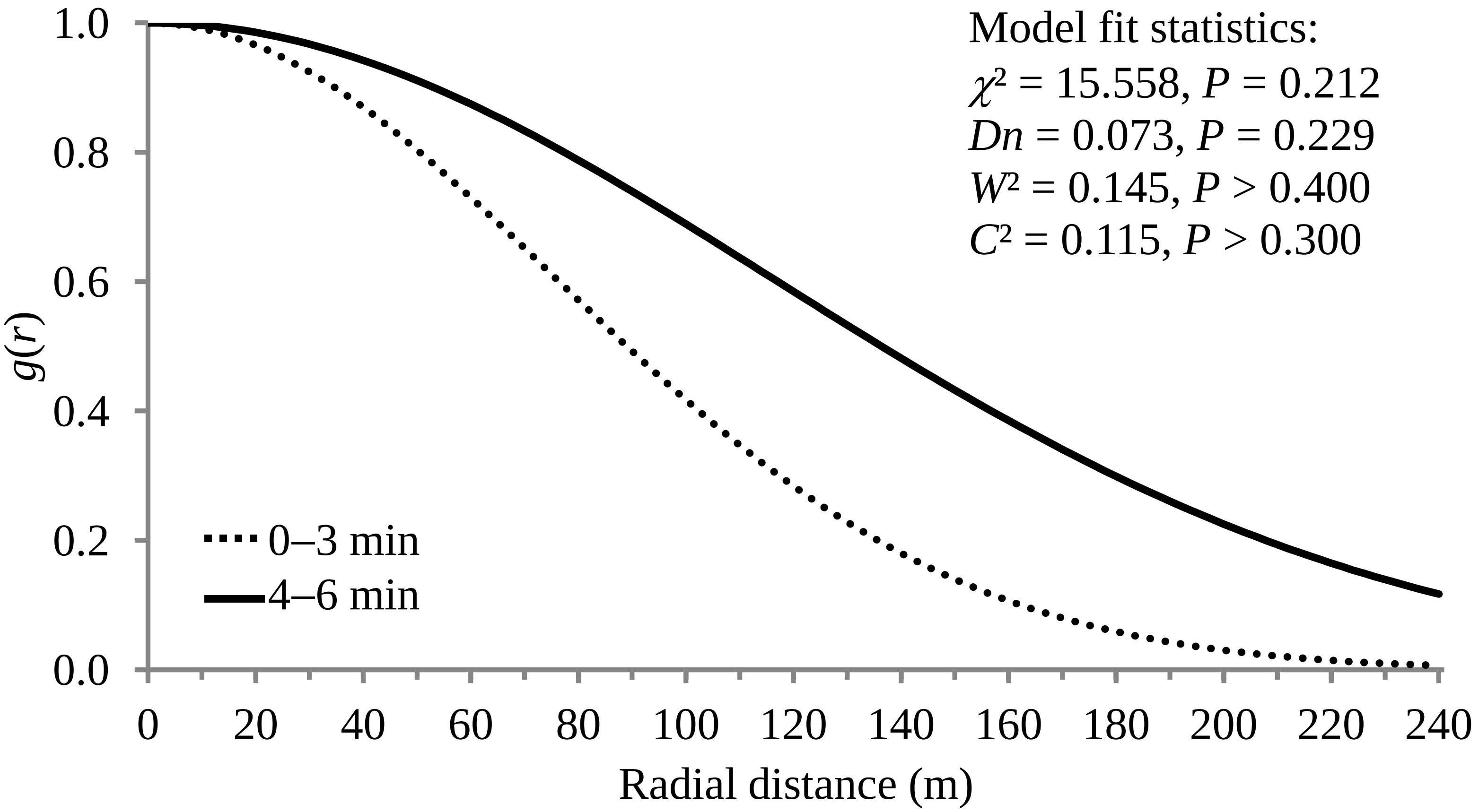


Figure 4. Detection function (half-normal key function without adjustment term and detection time as a covariate) based on YSPA survey data (n = 229) collected in March 2010–2012 and October 2010–2011



Model fit statistics:
χ^2 = 15.558, P = 0.212
Dn = 0.073, P = 0.229
W^2 = 0.145, P > 0.400
C^2 = 0.115, P > 0.300

Figure 5. Estimate of density (± SE) and detection time (2 3-min snapshots) based on YSPA survey data (*n* = 229) collected in March 2010–2012 and October 2010–2011

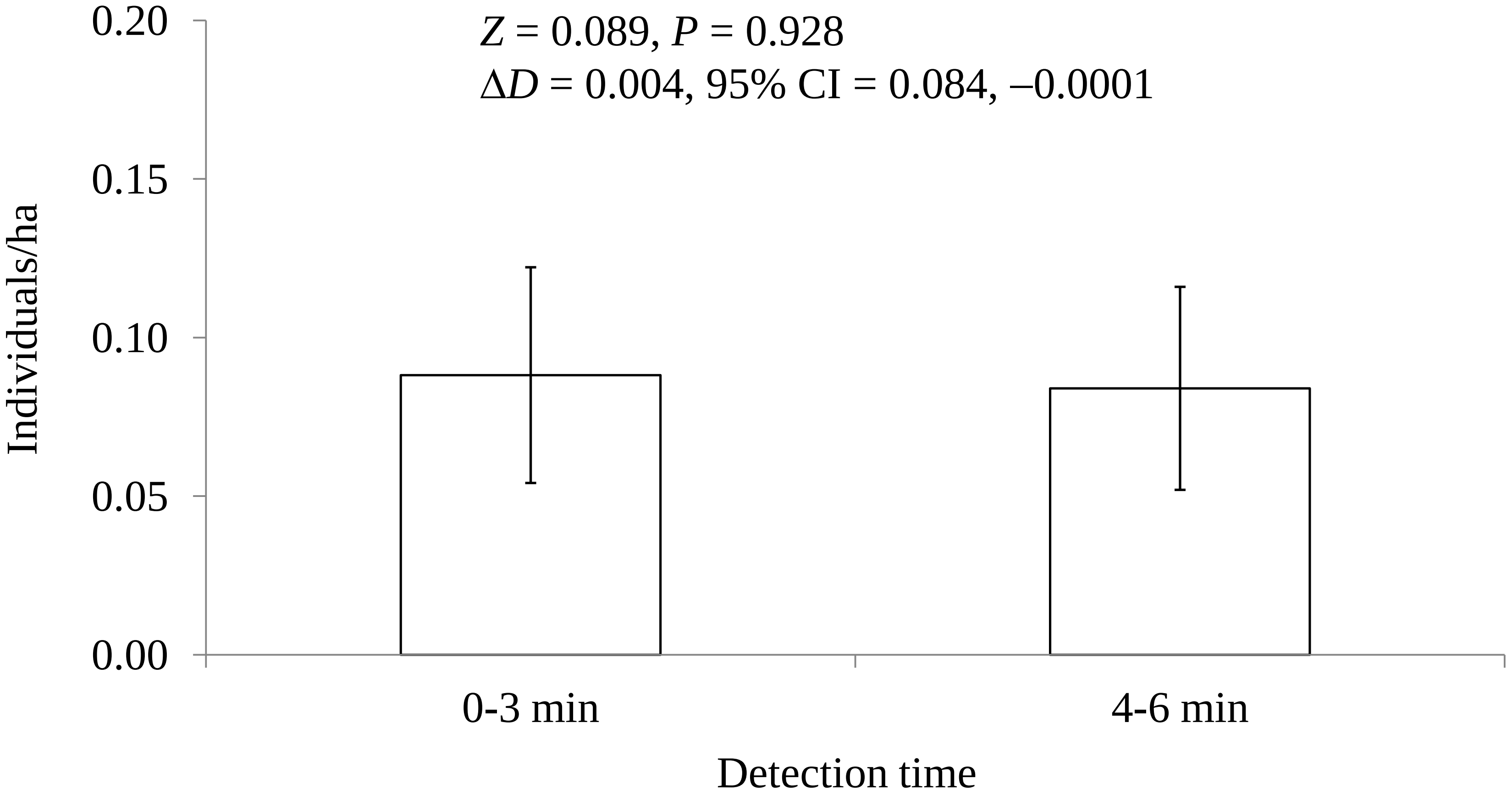
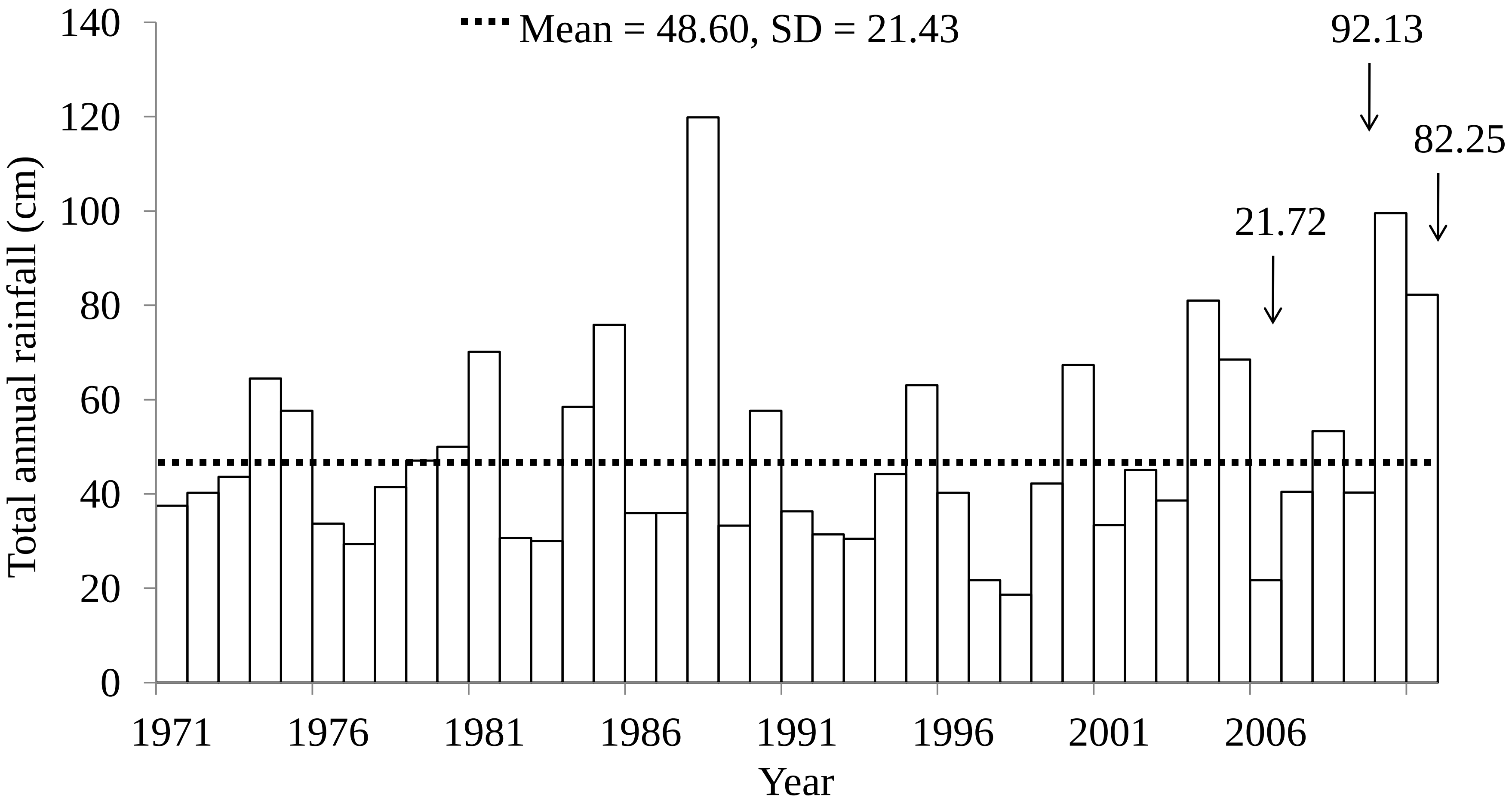
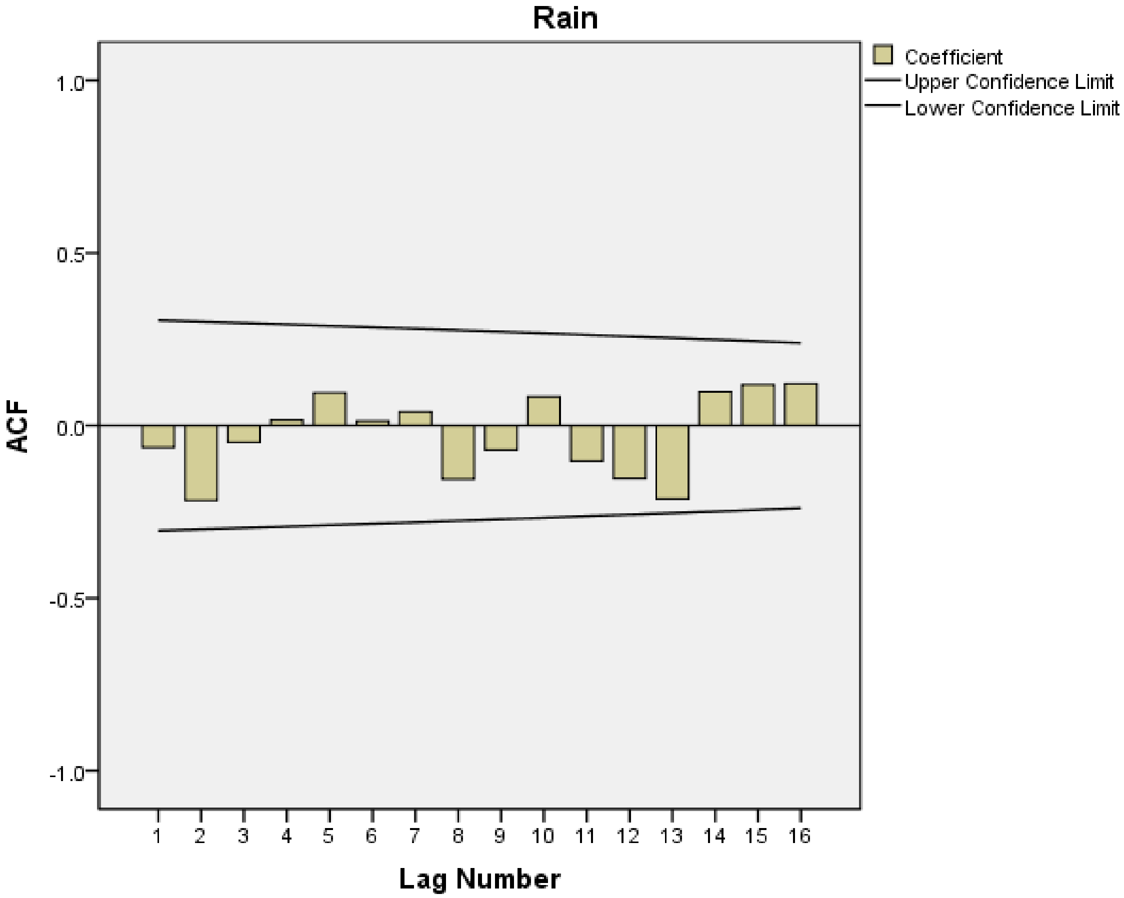


Figure 6. Total annual rainfall (cm) at Bonaire Flamingo Airport in 1971–2011



(Data provided by the Meteorological Department of Curacao)

Figure 7. Autocorrelation function of the rainfall time-series, showing a periodicity of about 5 years between wet periods



(Data from Meteorological Department of Curacao)

Figure 8. Total monthly rainfall (cm) at Bonaire Flamingo Airport in 1971–2011

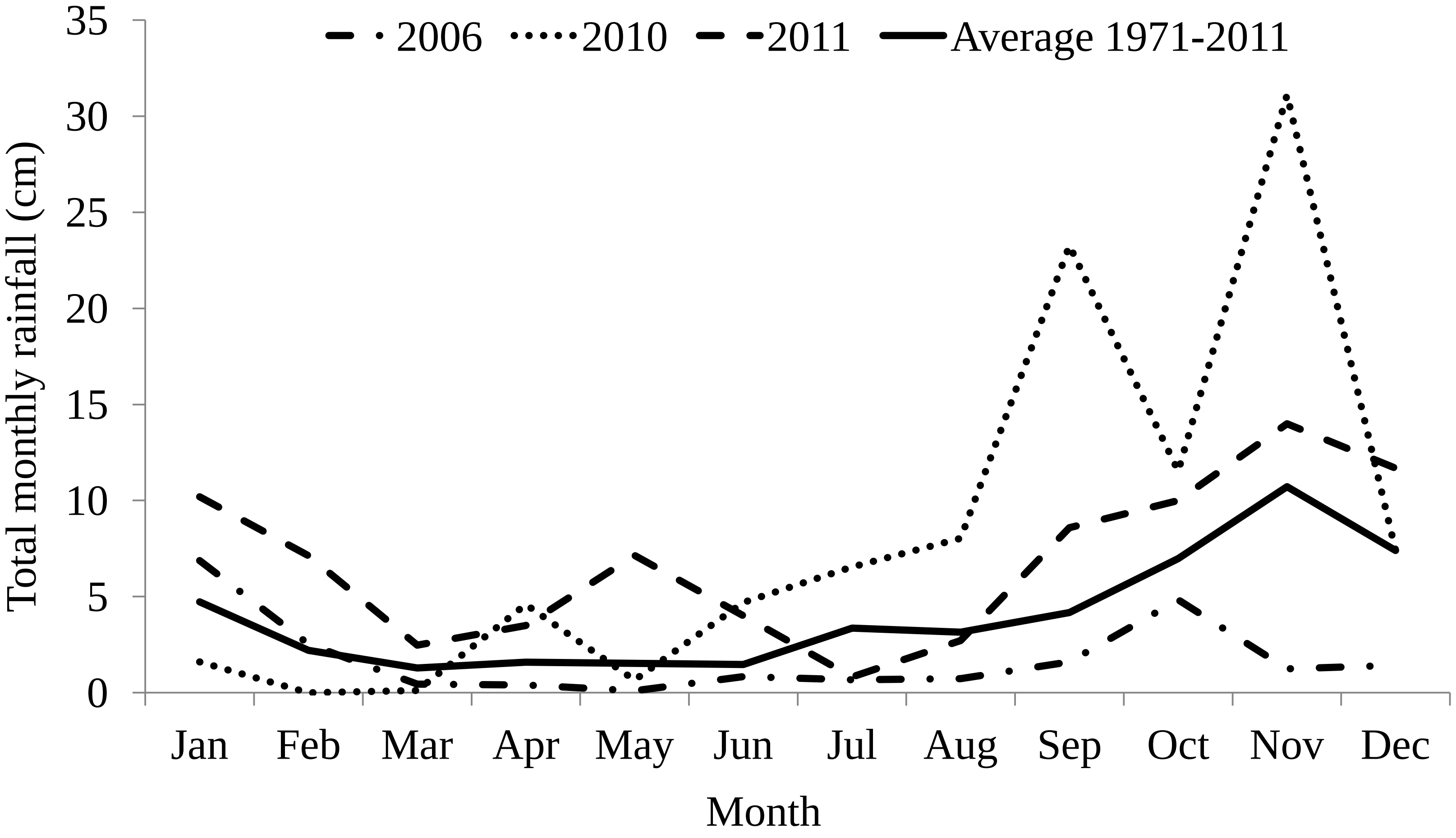
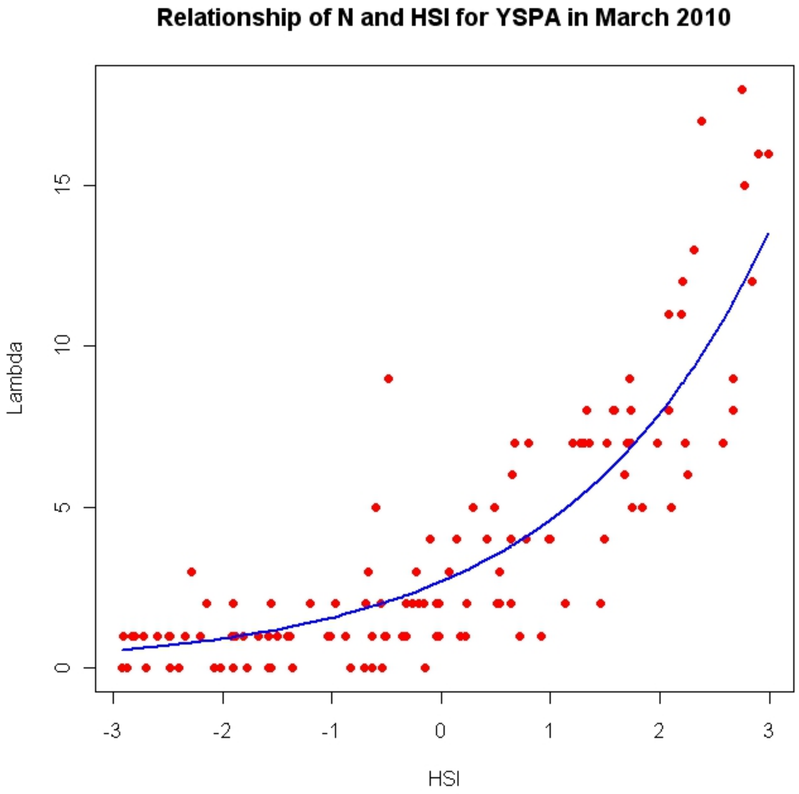


Figure 9. Estimated density vs. habitat suitability index (food abundance + food diversity + habitat availability – disturbance) based on YSPA survey data (*n* = 58) collected in March 2010



N-mixture model of best fit:

$$\log(\hat{\lambda}) = 0.989 + 0.539x$$

Parameter estimates:

$$\overline{\hat{\lambda}} = 3.802, 95\%\text{CI} = 2.213, 4.293$$

$$\overline{\hat{D}} = 0.170, 95\%\text{CI} = 0.122, 0.237$$

$$\overline{\hat{N}} = 2{,}895, 95\%\text{CI} = 2{,}079, 4{,}033$$

Figure 10. Random-systematic survey sampling scheme (k = 373 points) for a survey region (A) covering 18,000 ha in Bonaire

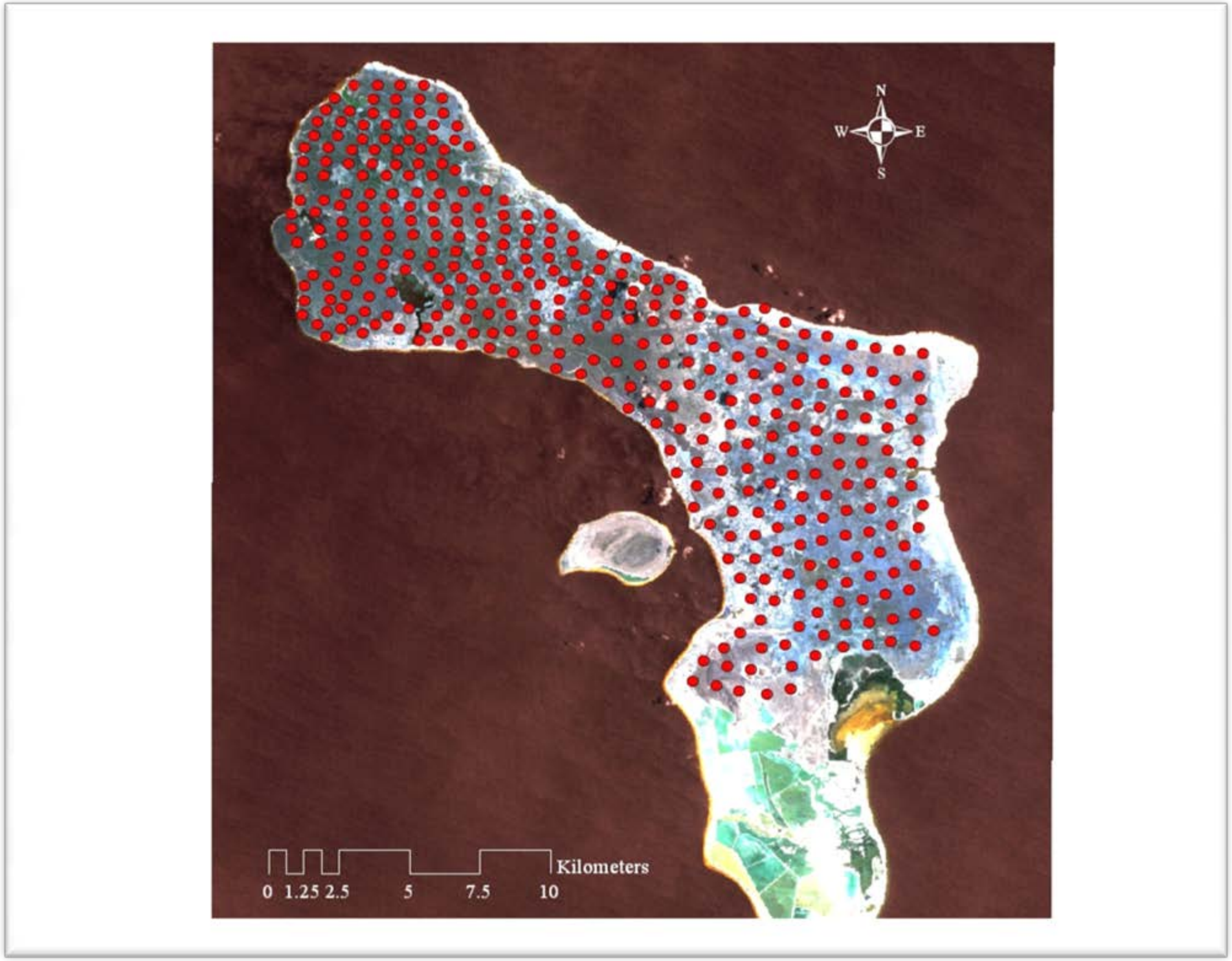


Table 1. Top 10 detection models (key function + adjustment term and covariate) based on YSPA survey data (*n* = 229) collected in March 2010 –2012 and October 2010 –2011

Detection model	Parameters	AIC	ΔAIC
HN + 0 (DT)	2	2,150.011	0
UN + 2 CO	2	2,168.994	18.98291
HN + 0 (HT2)	5	2,170.458	20.44702
HN + 0 (DF2)	2	2,170.629	20.61792
HN + 0 (SP)	4	2,171.090	21.0791
HN + 0	1	2,171.515	21.50391
HN + 0 (DF1)	2	2,171.717	21.70605
HN + 0 (TD)	2	2,172.420	22.40894
HR + 0	2	2,172.486	22.4751
HN + 0 (PL)	2	2,172.505	22.4939

Table 2. Estimates of YSPA detection probability (truncation distance *w* = 240 m) and effective radius of detection (m) based on YSPA survey data (*n* = 229) collected in March 2010 –2012 and October 2010 –2011

Parameter estimate	Mean	2.5%	97.5%
$\hat{P}_a$	0.205	0.175	0.240
$\hat{p} = w \times \sqrt{\hat{P}_a}$	109	101	118

Table 3. Estimates of YSPA density, population size, and rate of change before and after reproduction (births – deaths)

Density	Mean	2.5%	97.5%
Mar 2010	0.165	0.131	0.209
Oct 2010	0.192	0.152	0.243
$\Delta\hat{D}$	0.027	0.021	0.034
Population size	Mean	2.5%	97.5%
Mar 2010	2,810	2,229	3,544
Oct 2010	3,322	2,572	4,291
$\Delta\hat{N}$	512	343	747
$\hat{r}_t = \ln(\hat{N}_{t+1} / \hat{N}_t)$	0.167	0.143	0.191
$(\exp(\hat{r}_t) - 1) \times 100$	18.22%	15.39%	21.08%

Table 4. Estimates of YSPA density, population size, and rate of change before reproduction (births – deaths)

Density	Mean	2.5%	97.5%
Mar 2010	0.165	0.131	0.209
Mar 2012	0.161	0.127	0.203
$\Delta\hat{D}$	–0.004	–0.004	–0.006
Population size	Mean	2.5%	97.5%
Mar 2010	2,810	2,229	3,544
Mar 2012	2,731	2,163	3,448
$\Delta\hat{N}$	–79	–66	–96
$\hat{r}_t = \ln(\hat{N}_{t+1}/\hat{N}_t)$	–0.029	–0.030	–0.028
$(\exp(\hat{r}_t)-1)\times 100$	–2.89%	–3.05%	–2.71%

Table 5. Estimates of YSPA density, population size, and rate of change after reproduction (births – deaths)

Density	Mean	2.5%	97.5%
Oct 2010	0.192	0.152	0.243
Oct 2011	0.193	0.152	0.245
$\Delta\hat{D}$	0.001	–0.0006	0.002
Population size	Mean	2.5%	97.5%
Oct 2010	3,271	2,589	4,132
Oct 2011	3,276	2,578	4,162
$\Delta\hat{N}$	5	–11	30
$\hat{r}_t = \ln(\hat{N}_{t+1}/\hat{N}_t)$	0.002	–0.004	0.007
$(\exp(\hat{r}_t) - 1) \times 100$	0.15%	–0.43%	0.73%

Table 6. Estimates of YSPA density, population size, and rate of change after and before reproduction (deaths only)

Density	Mean	2.5%	97.5%
Oct 2011	0.193	0.152	0.245
Mar 2012	0.161	0.127	0.203
$\Delta\hat{D}$	–0.032	–0.025	–0.042
Population size	Mean	2.5%	97.5%
Oct 2010	3,276	2,578	4,162
Mar 2012	2,731	2,163	3,448
$\Delta\hat{N}$	–545	–415	–714
$\hat{r}_t = \ln(\hat{N}_{t+1} / \hat{N}_t)$	–0.182	–0.176	–0.188
$(\exp(\hat{r}_t) – 1) \times 100$	–16.64%	–16.10%	–17.16%

Table 7. Population conservation objectives based on YSPA survey data (*n* = 101) collected before reproduction in March 2010 and 2012

Parameter	Mean	2.5%	97.5%
Density (D)	0.163	0.132	0.201
Population size (N)	2,774	2,251	3,420
Encounter rate (n/K)	0.418	0.320	0.545
Occupancy (ψ)	0.417	0.328	0.533
Rate of change (r)	0.167	0.143	0.191
Interaction factor (φ)	0.908	0.903	0.914

APPENDIX 1

Review of master thesis titled "The problem with parrots: investigating effective sampling techniques for *Amazona barbadensis* on Bonaire", Phil Saunders (2011), Imperial College London

General Comments

Saunders′ MS thesis has problems with survey design (e.g., one observer conducting counts during the breeding season, when nesting females are not available for detection), count method (e.g., not accounting for the effect of survey and site specific covariates on detection using multiple-covariate distance sampling), and data analysis (e.g., overparameterization of detection models leading to imprecise density estimates). The thesis is not an investigation of the effectiveness of survey sampling design or distance sampling methodology (e.g., sampling coverage, method assumptions, precision, bias, and statistical robustness of the density estimator were not evaluated; Burnham et al. 2004, Fewster and Buckland 2004, Rivera-Milán et al. 2004, Buckland 2006). The effectiveness of roost counts was not evaluated either (e.g., the functional relationship between the relative abundance index and population density estimates, within-year and between-year count variation and the magnitude of sampling and nonsampling sources of error, and available methods for trend modeling and estimation; Thompson et al. 1998, Thomas et al. 2004, Rivera-Milán et al. 2012).

Saunders′ survey design and count method application led to imprecision (CV $\hat{D}$ = 0.57–177.59). However, our point estimates of density ($\hat{D}$) and population size ($\hat{N}$) were similar (Tables 3–7 in this report). He recommended using a "snapshot" count, which is in fact what we did conducting six 1-min consecutive counts/point , and accounting for detection time

(1 = 0–3 min, 2 = 4–6 min) in multiple-covariate distance sampling models. Rivera-Milán and Simal found that inclusion of detection time in detection models received empirical support from the distance data and increased the precision of the density estimator (Tables 1 and 3–7 in this report). However, detection time did not cause extreme heterogeneity in detection (see Figs. 3 and 4 in this report and compare with fig. 3 in Marques et al. 2007), and as a result density estimates did not differ between two consecutive 3-min counts/point (Fig. 5 in this report). The 3-min counts in essence represented "snapshots" as defined by Buckland (2006). (Note that parrots counted/min were removed and not counted again; i.e., time of first detection and distance were recorded for parrot singles and clusters within a radius of 440 m.)

Specific Comments

1) **Abstract, page 7, third paragraph.** A density estimate of 0.01 parrots/ha equals 221 parrots in a survey region covering 22,111 ha (i.e., $\hat{N}_t = \hat{D}_t \times A$). This must be a typo; see Saunders′ table 4.12 (page 39) were $\hat{D}$ = 0.098 parrots/ha (i.e., 0.10 not 0.01 after rounding) and $\hat{N}$ = 2,169 parrots in 22,111 ha. The 6-min point estimate of density ($\hat{D}$ = 0.10, SE = 0.06, CV = 0.57; table 4.12) was not statistically different from that of the "snapshot" count ($\hat{D}$ = 0.14, SE = 0.25, CV = 177.59; table 4.16). However, both density estimates were imprecise for a variety of reasons we discuss in this review.
2) **Introduction, study species, page 10, first paragraph.** Paraphrasing Saunders: "The population of YSPA on Bonaire benefited… from a decrease in poaching and removal of introduced mammals in the WSNP." Without an evaluation of roost counts, this statement implies a positive trend in the parrot population resulting from a reduction in poaching pressure and the removal of mammals from the WSNP. We discuss the

problems with roost counts later in this review. However, poaching is an ongoing problem (Williams and Evans 2010) and STINAPA has not undertaken any significant removal of introduced mammals from the WSNP. The facts are that the effect of poaching on viability has not been evaluated through population modeling, and that goat and pig densities are unknown but vegetation damage is evident inside and outside the the boundaries of the park.

3) **Introduction, page 11, second paragraph.** Saunders surveyed 137 points by himself during 6 weeks between 18 May and 24 June. That is, he conducted one visit/point during the breeding season, when nesting females are not available for detection. This is problematic when using conventional distance sampling, because in a closed population (no immigration or emigration) detection probability is the product of the probability that a parrot is available to be detected and the probability that the parrot is detected given availability during the count (i.e., $P = P_a \times P_{d|a}$). Parrots are distributed across the landscape in some stochastic manner (random, regular, or clumped) with rate parameter D (expected number/unit area). To justify an inference from the surveyed area (a) to the survey region(A) it is critical that sampling units (points) are random with respect to parrot distribution (Buckland et al. 2001, 2008). Rivera-Milán and Simal (two-observer team) conducted surveys before (March 2010–2012) and after (October 2010–2011) reproduction to increase parrot availability for detection. Given our experience and knowledge of the terrain, we covered remote areas and only needed about 8 days to survey 104 points in March 2010, 112 points in October 2010, 121 points in October 2011, and 124 points in March 2012. Based on the sample size needed for a CV $\hat{D}$ = 0.10–0.15, we are planning to survey 150 points in October 2012 (see Fig. 10 and the

Recommendations in this report). The inclusion of point location (PL, 1 = on road, 2 = off road) as a covariate in detection models did not receive empirical support from the distance data (Table 1 in this report). Rivera-Milán et al. (2005, unpublished data) found the same for parrot surveys in the Bahamas and Cayman islands.

4) **Problem statement, page 10, second paragraph.** Paraphrasing Saunders, "In order to assess the impact of any conservation program… it is imperative that an accurate, precise and cost-effective monitoring method is utilized to assess trends…" We reiterate that Saunders did not conduct a statistical evaluation of bias and precision, or of the cost-effectiveness of our (or his) survey sampling scheme and count method application.

5) **Problem statement, page 10, third paragraph.** Buckland et al. (1993, 2001) offered an introduction to distance sampling (so-called "conventional" or "standard" distance sampling). However, multiple-covariate distance sampling (Marques and Buckland 2004, Marques et al. 2007) represents an important extension of distance sampling theory not considered by Saunders.

6) **Problem statement, page 10, fourth paragraph.** Through a random-systematic survey sampling scheme (k = 188 points; Fig. 1 in this report) and a combination of count methods (conventional, multiple-covariate, and hierarchical distance sampling, count-removal and repeated-count sampling), we accounted for factors related to parrot behavior (e.g., clustering and clumping) and habitats that were occupied or potentially occupied on the island. We needed about 8 days to survey 104–124 points in March 2010–2012 and October 2010–201, and the coefficient of variation (CV $\hat{D}$ = mean $\hat{D}$ /SE) ranged from 0.11 to 0.20 (Tables 3–7 in this report). Saunders conducted a six

weeks survey during May–June 2011, and CV $\hat{D}$ was 0.57 for the 6-min count and 177.59 for the "snapshot" count.

7) **Problem statement, page 11, first paragraph.** We included detection time (1 = 0–3 min, 2 = 4–6 min) as a covariate in detection models, and estimated densities did not differ between consecutive 3-min counts/point. Saunders criticized the use of a 6-min count on the basis of undetected parrot movement, but he proceeded to conduct a 6-min count, followed by a "snapshot" count. An "instantaneous" count (say, 1–2 min) is inefficient in terms of the number of parrot detections (*n*), precision of the density estimator (CV $\hat{D}$), and negligible parrot movement near point centers (Rivera-Milán et al. 2005, unpublished data). In fact, Buckland (2006) recommended a 3-min "snapshot" count after arriving to a point. Rivera-Milán and Simal did essentially that, but added flexibility to data analysis by including detection time as a covariate in distance sampling models, and testing the hypothesis of no difference in detection and density estimates between two 3-min counts/point. Saunders did not provide information about the duration of the "snapshot" count (1 min, 2 min, 3 min?; Section 3.2.2. Distance sampling, pages 27 and 28). Regardless, Saunders′ point estimates of density were not statistically different for the 6-min and "snapshot" counts (0.10 parrots/ha and 0.14 parrots/ha, respectively). Moreover, in the Discussion (Section 5.2.3.2. Length of point count sampling period, page 47, fourth paragraph), he stated that the "evidence of surveyor-induced flushing from, or attraction towards, point locations during access was limited (pers. obs.) and its impact upon the current study is considered to be negligible." Saunders measured detection distances and recorded ancillary data at points by himself.

Two observers working as a team increased the chance of meeting method assumptions and increased the number of aural and visual detections per point that were considered accurate for density estimation (Burnham et al. 2004, Rivera-Milán et al. 2005, unpublished data).

8) **Background, page 14, second paragraph:** Paraphrasing Saunders, "… the application of any particular survey method within a distinct geographic location at differing temporal or seasonal points may produce significantly different population estimates." Distance sampling is pooling robust, meaning that not accounting for covariates other than distance would not bias overall density unless detection heterogeneity is extreme (see, e.g., Marques et al. 2007: fig. 3). Sampling period (SP, 1 = March 2010, 2 = October 2010, 3 = October 2011, 4 = March 2012) was not an important covariate, meaning that pooling the islandwide survey data of four sampling periods provided a more parsimonious and informative approach to modeling the detection function (Buckland et al. 2001, 2004, 2008; Alldredge et al. 2007). Using information theory (Akaike Information Criterion), we analyzed the distance data with a common detection function for all sampling periods and habitat types (HT1, 1 = dry forest, 2 = dry scrub, 3 = mixed forest-scrub, 3 = urban with mixed vegetation, 4 = agriculture with mixed vegetation; or HT2, 1 = lower terrace, 2 = middle terrace, 3 = higher terrace, 4 = escarpment, and 5 = undulating, following De Freitas et al. 2005), with different detection functions for each sampling period and habitat type through stratification or poststratification, and with a common detection function and sampling period and habitat type as covariates. Survey effort accounted for the number of visits/point (i.e., $v = 1–4$ visits to $k = 157$ points), producing consistent density estimates in March 2010–2012

(before-reproduction surveys) and October 2010–2011 (after-reproduction surveys; Tables 3–7 in this report).

9) **Background, page 14, third paragraph.** We agree with Saunders that roost counts can be problematic for a number of reasons. Our main concern has been the misuse of roost counts to estimate population size or "national abundance" on Bonaire (Birdlife International 2008, Williams 2009). Roost counts do not represent a census of roosting areas (i.e., incomplete coverage). Small and inaccessible roosts are less likely to be included in the counts than large and accessible roosts. Roost counts do not represent a census of parrots at roosting areas (i.e., imperfect detection). Potentially important covariates have not been considered to adjust roost counts for imperfect detection (e.g., number and experience of observers, number of sites in which counts are conducted annually, vegetation cover at different sites, and cluster size of parrots). In addition, many parrots do not use communal roosts or show typical roosting behavior (i.e., they are not available to be counted). We have discussed these issues in previous reports and emails to B. Denneman (May 10, 2010), S. Williams (July 1, 2010), and J. Gilardi (October 19, 2010).

10) **Detection at point center, *g*(0) = 1, page 17 second and third paragraphs.** We are confident that this assumption was met, regardless of parrot behavior (calling or not calling, singles or clusters) and habitat type (see the Discussion of distance sampling assumptions in this report). However, note that failure to meet this assumption would have underestimated density (Buckland et al. 2001, 2008).

11) **Identification of birds at original locations, pages 18 and 19.** We consider that we met this assumption by having a two-observer team and using distance categories (see the

Discussion of distance sampling assumptions in this report). We agree with Saunders that parrot movement in response to observers appeared to be negligible. In any event, movement seemed to be away from points in most instances, which again would have underestimated density (Buckland et al. 2001).

12) **Accurate measurements of distances and other considerations, pages 19–21.** We consider that exact distance measurements (visual contact) and category allocations (no visual contact) did not bias density estimation. The same two-observer team surveyed all points, with one observer recording the data and the other measuring detection distances. Both observers remained side by side for 6-min, recording the time of first detection (six 1-min intervals) and measuring radial distances to calling and noncalling parrots detected singly or the geometric center of clusters. A 6-min count increased the chance of detecting calling parrots visually. However, when this was not possible, we measured the distance to the nearest horizontal location (Burnham et al. 2004) and allocated detections to 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, unpublished data). The use of rangefinders and distance categories reduced distance measurement errors, because in most instances we were able to approximate the location of calling parrots. We did not include moving parrots in density estimates, unless their initial locations were ascertained during or immediately after the 6-min count. Moreover, we spent 1–5 min after the count double-checking detection distances and ancillary data. We included detection form as a covariate in multiple-covariate distance sampling models (DF1, 1 = heard only [i.e., no visual contact], 2 = heard-seen or seen only [visual contact]; or DF2, 1 = heard [visual or no visual contact], 2 = seen only; Marques et al. 2007). We made 229 detections of

parrot singles and clusters (*n*) in 157 points (*k*) surveyed 1–4 times (*v*) in March 2010–2012 and October 2010–2011; 58 of these detections were of parrots heard only (i.e., no visual contact) and 171 detections were of parrots heard-seen or seen only (visual contact). Detection time (1 = 0–3 min, 2 = 4–6 min) was the only covariate that caused heterogeneity in the detection function. However, this heterogeneity was not extreme and did not bias density estimation. Models of the detection function are pooling robust, meaning that data pooling over many factors (detection time, sampling period, detection form, and habitat type) the density estimator (Buckland et al. 2001, 2008; Burnham et al. 2004, Marques et al. 2007).

13) **Other survey methods pages 21 and 22.** This is a poor review of available methods for parrot surveys. For example, cue-count survey (Buckland 2006), hierarchical distance sampling and repeated-count sampling (Royle and Dorazio 2008), as well as active and passive approaches to detection and density estimation using advanced distance sampling methods (Buckland et al. 2004, 2006) were not even mentioned. Rivera-Milán and Simal combined count methods to increase the flexibility of data analysis at point level (Fig. 9 in this report) and across points (Tables 1–7 and Figs. 1–5 in this report). Hierarchical distance sampling, for example, extended distance sampling theory by modeling the effect of covariates on both detection and density using maximum likelihood and Bayesian approaches (Royle et al. 2004, Royle and Dorazio 2008).

14) **Methods, Section 3.1, Survey design, pages 24–26**. Saunders and Rivera-Milán and Simal used similar approaches to sampling design (e.g., compare fig. 3.1 in Saunders and Fig. 1 in this report). We used ArcGIS and Google Earth analysis tools to establish random-systematic points in 17,000 ha, excluding waterbodies and bareground areas with little or no

vegetation. We used a 1-km² (100 ha) sampling grid to establish 188 points in a random-systematic manner. Neighboring points were separated by a minimum distance of 400–500 m in rugged terrain and dense vegetation. Points were separated by 500–1,000 m inside the WSNP and 500–1,600 m in farmland and urban areas of northern, central, and southern Bonaire. A systematic procedure (*n*-in-*k* design) simplified the process of sampling unit selection (Thompson et al. 1998, Scheaffer et al. 1990). To secure adequate randomization and replication, we selected a new random start every 10 points (i.e., 1-in-10 systematic sampling design). By the way, double-counting between points is not a problem and therefore is not a necessary assumption of distance sampling. This is because the variance of *n* is estimated from variation in encounter rate (*n*/*K*) between replicate points in the survey region, making the method robust to violation of the assumption of sampling unit (point) independence (Buckland et al. 2001, 2008; Buckland 2006).

15) **Field survey, page 26**. Saunders conducted the surveys during 6 weeks between 18 May and 24 June 2011, when nesting females were not available for detection. He conducted the surveys by himself and points were visited only once. Not surprisingly Saunders had problems with aural detections (no visual contact) and needed a rather long sampling period to survey 137 points (*k*) and obtain a sample size (*n*) of 63 detections. We note that this is not a small sample size to estimate density across points when data quality is good (e.g., a detection function with a broad shoulder that monotonically declines with distance from point center; Fig. 4 in this report, but also see Rivera-Milán et al. 2005).

16) **Roost counts**, **Sections 3.2.1, 3.3.2, and 5.1.2.** Saunders did not conduct roost counts and provided an uninformative scatterplot of roost count trend (fig. 4.6). No real attempt was made to evaluate data collection procedures, within-year and between-year count variation,

the magnitude of process and observation errors, the effects of site and count specific covariates (e.g., observers and vegetation cover), and trend analysis methods (Thomas et al. 2004, Rivera-Milán et al. 2012). We conducted three roost counts at Shubert′s Farm. We counted 600+ parrots in March 2010, 400+ parrots in October 2010, and 497 parrots in March 2012. In the first two occasions we missed parrots already present and not leaving the roost. In the last occasion, however, we did not see or hear parrots when we arrived to the vantage point (15:45 hrs), and we added a third observer to count parrots flying from different directions; two observers were at ground level and one observer was in a crane basket above canopy level; the three observers were positioned between 10 and 50 m of each other, along the same dirt road, and in constant communication to avoid double-counting and subtract from the count parrots leaving the roost. Citing Saunders, "the roost count undertaken on Bonaire in February 2011 produced a minimum population estimate of 550 YSPA" (Section 5.2.1 Roost counts, page 44, third paragraph). However, in the three occasions we saw other roosting areas active, and there were many parrots that did not show roosting behavior. The vegetation at Shubert′s Farm is high and dense, and parrot singles and clusters fly low above the canopy and continue entering the roost as it is getting dark. Therefore, we did not conduct a complete count or census of roosting parrots (i.e., detection probability $P < 1$). We have been very specific about the problems with roost counts on Bonaire: (1) there is no well-defined sampling frame of roosting areas, and therefore no probabilistic framework to justify an inference beyond the specific roosts visited at any given time; and (2) detection probability of roosting parrots is imperfect. Roost counts that do not account for coverage and detection should not be used to estimate population size.

Moreover, roost counts without any estimate of variation should not be used to support the claim of a positive trend in the parrot population.

17) **Results and discussion about distance sampling, pages 35–53.** Saunders′ point estimates of density were similar to ours. However, Saunders′ estimates of variation (SE, CV) reflected imprecision for a variety of reasons. Saunders conducted the surveys by himself (single observer), when nesting females were not available for detection. He conducted the "snapshot" count at the end of the 6-min count. Saunders did not use distance categories to relax method assumptions. He did not use multiple-covariate distance sampling to account for the effect of survey and site specific covariates. Rivera-Milán and Simal (this and previous reports) found that distance sampling models with covariates reduced heterogeneity in the detection function and therefore increased the precision of the density estimator. Saunders did not truncate the distance data and used the hazard-rate key function (2 parameters) with a cosine adjustment term (1 parameter; tables 4.9 and 4.13, figs. 4.10–4.15). Truncation of distance data, when detection probability $g(r) < 0.10–0.15$, is recommended to remove outliers, reduce bias in estimating cluster size, and increase method robustness to estimate detection with flexible but not overparameterized models (Buckland et al. 2001). Rivera-Milán and Simal truncated the data at distance $w = 240$ m (Figs. 2 and 4 in this report). Based on information theory (AIC), we selected the half-normal key function with no adjustment term (1 parameter) and detection time (1 parameter) as a covariate to account for heterogeneity in the detection function (Table 1 and Figs. 3–5 in this report). The wide shoulder of the detection function reflected high detection probability ($P > 0.60$) up to about 80 m from point centers. The quantile-quantile plots and goodness-of-fit tests indicated good data quality, particularly near point centers (Fig. 4 in this report). By the way, contrary to

what Saunders stated (page 46, fourth paragraph), Rivera-Milán et al. (2005: figs. 1 and 2) truncated the distance data of parrots in the Bahamas ($w = 180–240$ m).

18) **Discussion, Section 5.1.1, page 43, third paragraph**. The inclusion of point location (PL, 1 = on road, 2 = off road) in multiple-covariate distance sampling models did not receive support from the distance data (Table 1 in this report; Rivera-Milán et al. 2005, unpublished data). Off-road points were ≥ 200 m from nearest road or trail. We did not cut pathways through the vegetation, but we agree with Saunders that this would save time and increase the number of points that can be surveyed per sampling period (see the Recommendations in this report).

19) **Discussion, Section 5.2.2., page 45, fourth paragraph.** Saunders did not provide measures of variation for the estimates of detection probability and effective radius of detection. However, because he conducted the “snapshot” count after the 6-min count, it is not surprising that availability to be detected (P_a) and detection given availability ($P_{d|a}$) dropped sharply near point centers, decreasing sample size ($n = 20$ visual detections) and making the density estimator imprecise (table 4. 16 and fig. 4.14). Definitely this was not the case for two experienced observers working as a team; detection remained high ($P > 0.6$) up to about 80 m and decreased monotonically with increasing distance from point centers (e.g., compare Saunders′ figs. 4.8, 4.10, and 4.14 with Figs. 2 and 4 in this report).

20) **Discussion, Section 5.2.2., page 46, first paragraph.** A density of 0.01 parrots/ha extrapolated to 22,111 ha equals 211 parrots. Rounding to two decimal points, $\hat{D} = 0.10$ parrots/ha and therefore $\hat{N} = 2{,}169$ parrots (see table 4.12, page 39). Saunders′ point estimates for the “snapshot” count were 0.14 parrots/ha and 3,127 parrots in 22,111 ha (table 4.16, page 42). Paraphrasing Saunders, “both population estimates compare well with the

average density of 0.17 parrots/ha and population size of 2,829 parrots produced for Bonaire by Rivera-Milán and Simal" in March 2010 (Table 3 in this report). Note that we avoid using the word "minimum" but provide the lower 2.5% limit of the bootstrapped 95% confidence interval (i.e., 2,229 parrots before reproduction in 17,000 ha; Table 3 in this report).

21) **Discussion, Subsection 5.2.3.1, page 46, fourth paragraph.** Buckland et al. (2001, 2008) gave a general rule-of-thumb about the sample size (n = 75–125) needed to model the detection function using point-transect distance sampling data. However, the adequacy of sample size depends on data quality and the distribution of singles and clusters throughout the survey region (with dispersion parameter $b \geq 3$ meaning high clumping; Buckland et al. 2001). That is, smaller sample sizes (e.g., n = 40–60) may suffice for modeling the detection function and estimate density with precision when dispersion parameter $b < 3$ and data quality is good (wide shoulder, slow, monotonic decline; Fig. 4 in this report; also see Rivera-Milán 2005:figs. 1 and 2). Some amount of data truncation (w = 240–340 m in the case of Saunders′ dataset; see fig. 4.8, page 37) is always recommended to remove outliers, improve the fit of detection models, and increase detection probability near point centers (Buckland et al. 2001). The choice of truncation distance (w) depends on data quality, and it always represent a tradeoff between sample size, precision, and robustness of the density estimator (i.e., similar density estimates by different detection models).

22) **Discussion, Subsection 5.2.3.1, page 47, first paragraph.** Sampling period was not an important covariate affecting detection and therefore density estimation, and we accounted for survey effort/point using standard distance sampling methodology (Buckland et al. 2001). Distance sampling is pooling robust and therefore unless there is substantial heterogeneity in

detection there is nothing fundamentally wrong with combining data from different sampling periods and habitat types using information theory for model selection and inference (Buckland et al. 2001, Alldredge et al. 2007). Moreover, distance sampling is robust against double-counting between points (Buckland et al. 2001, Burnham et al. 2004, Buckland 2006). In fact, these are common misunderstandings of distance sampling theory and application, and there is little merit in the statements made by Saunders in this section. Rivera-Milán et al. (2005) and Rivera-Milán and Simal (this and previous reports) were diligent in the application of a combination of count methods to account for covariates that may affect both detection and density. Our distance sampling data had good quality and therefore sample sizes (*n*) of about 50–75 detections per sampling period sufficed for modeling the detection function and estimating density with precision (CV $\hat{D}$ = 0.11–0.20). Based on years of experience conducting distance-sampling surveys and recording time of first detection/min as part of standard survey procedures, we consider that 6-min counts (i.e., six 1-min counts/point) add flexibility to data analysis and represent an adequate tradeoff between increasing detection and decreasing undetected movement near point centers, which in the case of parrots in the Bahamas, Caymans, and Bonaire, tends to be away from the observers.

23) **Discussion, Subsection 5.2.3.2, page 47, third paragraph.** Saunders shows inconsistency when he states that “use of the ‘snapshot’ method (following what was, in effect, a 6 minute ‘settling in’ period) did however allow more time to accurately locate, count and measure the distance to any parrot present.” And that “the movement of parrots initially sighted during the 6 minute sampling period (and thus counted in the 6 minute dataset) away from the survey area, prior to the ‘snapshot moment’ is a potential issue however.” Indeed, Saunders′

application of the "snapshot" count was problematic. Citing Buckland (2001:249), "survey data for which the detection function drops off quickly with distance from the line or point, with a narrow shoulder and long tail, are far from ideal (fig. 2.1). Model selection is far more critical and precision is compromised". Buckland's statement identifies the main difference between Saunders′ data (i.e., one observer, quick decline in detection, detection function with narrow shoulder and long tail, no data truncation, use of hazard-rate key function with cosine adjustment, no covariates, imprecision) and our data (two observers, slow decline in detection, detection function with a broad shoulder and shortened tail by data truncation, use of half-normal key function without adjustment term, detection time as a covariate, precision).

24) **Discussion, Subsection 5.2.3.4, page 49, third paragraph.** The presence of caracaras and parakeets did not cause heterogeneity in the detection function of parrots (Table 1 this report). Examination of this kind of factor covariate (0 = not detected, 1 = detected) is easy within the multiple-covariate distance sampling engine of program Distance.

25) **Discussion, Subsection 5.2.3.5, page 50, first paragraph.** The use of rangefinders by two observers during and after 6-min counts usually allowed visual contact with calling parrots. Therefore, we consider that exact distance measurements and category allocations did not bias density estimation. We made 229 detections of parrot singles and clusters (*n*) in 157 points (*k*) surveyed 1–4 times (*v*) in March 2010–2012 and October 2010–2011; 58 of these detections were of parrots heard only (i.e., no visual contact) and 171 detections were of parrots heard-seen or seen only (visual contact).

26) **Discussion, Subsections 5.2.3.6 and 5.2.3.7, page 51, first and third paragraphs.** We have pointed out repeatedly that distance sampling is pooling robust. Habitat type (HT1, 1 =

dry forest, 2 = dry scrub, 3 = mixed forest-scrub, 3 = urban with mixed vegetation, 4 = agriculture with mixed vegetation; or HT2, 1 = lower terrace, 2 = middle terrace, 3 = higher terrace, 4 = escarpment, and 5 = undulating) was not an important covariate. Data pooling across spatial and temporal scales was justified according to information theory analysis within program Distance (Table 1, Fig. 4) and exploratory data analysis and statistical testing outside program Distance (Figs. 2 and 3).

27) **Discussion, Section 5.3, page 53, third paragraph.** Another example of Saunders′ inconsistent statements; here he states that "despite not necessarily providing an estimate of true density… distance sampling does still potentially comprise an important tool in the monitoring of the YSPA on Bonaire when compared to roost counts, as the latter method will only ever be able to provide a minimum population estimate in its current configuration". But in page 16, he states that "distance sampling is a well-recognized method of generating population estimates." And in page 21, he states that "in conclusion, whilst distance sampling allows the generation of real density and population size estimates, rather than indices of abundance, it is still potentially subject to varying levels of bias." Distance sampling generates absolute density estimates within well-defined survey regions (Buckland et al. 2001, 2004, 2008; Buckland 2006; Marques et al. 2007; Thomas et al. 2010). As any count method, however, distance sampling relies on basic assumptions that need to be met to estimate detection and density with negligible bias. In this report and thesis review, we have provided detailed information about the correct application distance sampling theory. Moreover, we have paid particular attention to survey sampling design and the combination of count methods to add flexibility to data analysis. Our goal is to make science informative and relevant to those organizations responsible for the management and conservation of

parrots and their habitats on Bonaire. With this and the most cost-effective allocation of financial resources in mind, we will soon review the monitoring strategy currently under consideration.

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