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TEST OF PARTNERS IN FLIGHT EFFECTIVE DETECTION DISTANCE FOR CERULEAN WARBLER

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Abstract. Estimation of population sizes of North American avian species has been attempted in the North American Landbird Conservation Plan. Such estimated numbers have considerable conservation value as starting points to estimate extinction probability, as was done for Cerulean Warbler (*Dendroica cerulea*) during the U.S. Fish and Wildlife Service evaluation of the petition to list the species as Threatened. Population estimates presented in the Flight Plan reflect assumptions applied to counts reported by observers on Breeding Bird Survey routes. One of these assumptions is the assignment of species to effective detection distance radii. We chose to test the assumption that effective detection distance of 125 m for Cerulean Warbler was an adequate value in bottomland hardwood and other forests in the species' breeding range. We randomly selected roadside and off-road locations, visited each multiple times with multiple observers, and used hand-held Global Positioning System units to measure the distance between count station and birds detected aurally. We used multiple covariate distance sampling to analyze these data in Program Distance. Our best estimate of effective detection distance is 94 m (95% CI 88–101 m), significantly lower than 125 m. Consequently, the total population estimate of Cerulean Warbler in the North American Landbird Conservation Plan, 560 000, should be revised to approximately 875 000; assuming all other factors involved in the calculation of total population remain equal.

Key Words: Cerulean Warbler, *Dendroica cerulea* distance sampling, effective detection distance, population estimation.

EVALUACIÓN DE DISTANCIA EFECTIVA DE DETECCIÓN PARA LA REINITA CERÚLEA (*DENDROICA CERULEA*) SELECCIONADA POR COMPAÑEROS EN VUELO

Resumen. Estimar el tamaño de las poblaciones de aves en Norte América forma parte del Plan de Vuelo de la organización Compañeros en Vuelo. El valor de conservación de estos estimados reside en su utilidad como punto de partida para poder estimar probabilidad de extinción de especies como la Reinita Cerúlea (*Dendroica cerulea*). Esos estimados fueron utilizados durante el proceso de revisión que llevo a cabo el Servicio Federal de Pesca y Vida Silvestre para atender la solicitud de listado para la especie bajo el Acta de Especies en Peligro de Extinción. Los estimados poblacionales presentados en el Plan de Vuelo reflejan premisas aplicables a los conteos reportados en el censo anual de aves durante la época reproductiva (BBS, por sus siglas en ingles). Una de estas premisas consta de asignar cada especie a un radio efectivo de detección. En este trabajo evaluamos la validez del radio de detección de 125 m establecido para la Reinita Cerúlea en distintos tipos de bosque dentro de su rango reproductivo. Seleccionamos localidades al azahar dentro y fuera de caminos las cuales visitamos en varias ocasiones con múltiple observadores y usamos unidades portátiles de GPS para determinar la distancia entre las estaciones de conteo y los individuos detectados auditivamente. Utilizamos muestreo a distancia en un diseño de covariables múltiples analizado en el programa Distance. El mejor estimado para distancia efectiva de detección fue 94 m (95% CI 88–101 m) lo que es significativamente menor a 125 m. Por tanto, los estimados poblacionales para la Reinita Cerúlea presentados en el Plan de Vuelo de 560 000 individuos deben ser modificados a unos 875 000, asumiendo que todos los otros factores envueltos en este cálculo permanezcan igual.

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INTRODUCTION

Estimation of global population size for biological species is a task generally restricted to species with small populations of limited geographic scope. Accurate estimation of population size is useful for assessing risks of various threats to populations in terms of mortality factors, and in estimating time to extinction based upon modeled population growth rates. The utility of making such population estimates for the variety of species in an entire fauna has been further demonstrated in the Partners in Flight North American Landbird Conservation Plan (Flight Plan; Rich et al. 2004).

Taking advantage of the continent-wide coverage of the Breeding Bird Survey (BBS; Robbins et al. 1986), Rich et al. (2004) produced a set of population estimates for most North American landbirds. The procedure for calculating the estimates is described in Rich et al. (2004), elaborated by Rosenberg and Blancher (2005), and revised in Blancher et al. (2007). Thogmartin et al. (2006) provide an independent evaluation of the procedure. The method involves evaluating the average number of registrations recorded on BBS routes within a particular area, correcting or adjusting that number of registrations to account for detectability, and then applying the resulting estimate of point density to the entire area or region.

Embedded in this procedure is an assumed effective detection distance, believed to be typically larger than the effective detection distance arrived at by analytical methods such as those produced by distance sampling analyses (Buckland et al. 2001), as exemplified in Program Distance (Thomas et al. 2005). Thomas et al. (2002) define effective detection distance, or effective strip (half) width, as that distance from the counting station "for which as many objects are detected beyond as are missed within"; we follow that usage here. The area around each counting station, and hence the total survey area calculated using this assumed distance has a profound effect on the ultimate size of estimated populations. Thogmartin et al. (2006) point out that few empirical data exist for appropriate estimation of detection distances from BBS data.

Such estimated population numbers have considerable conservation value as starting points to estimate extinction probability, as was done for Cerulean Warbler (*Dendroica cerulea*) during the U.S. Fish and Wildlife Service evaluation of the petition to list the species as Threatened (U.S. Fish and Wildlife Service 2006a, 2006b). We chose to test the assumption in Rich et al. (2004) that effective detection distance of 125 m for Cerulean Warbler was an adequate value in bottomland hardwood and other forests in the species' breeding range.

METHODS

We identified random locations in Hatchie National Wildlife Refuge, Fayette Co., Tennessee; Chickasaw National Wildlife Refuge, Lauderdale Co., Tennessee; Meeman Shelby Forest State Park and Wildlife Management Area, Shelby Co., Tennessee; and Center Hill Lake Recreation Area, DeKalb, Co., Tennessee. Each of the study areas is characterized by large tracts of deciduous forest.

Roadside locations in each of the areas were established systematically from a random starting point, and placed 800 m apart when surveys were conducted from vehicles, and 500 m apart when surveys were conducted on foot.

Off-road locations were established on existing study areas in Cerulean Warbler habitat in Chickasaw National Wildlife Refuge and Meeman Shelby Forest State Park and Wildlife Management Area. In each of these study areas, we selected grid points on existing 50 x 50-m grids such that points were 250 m apart. Off-road locations on Hatchie National Wildlife Refuge were established at randomly selected grid intersections of a 300 x 300-m grid laid across areas in the Refuge in which Cerulean Warblers were known to occur.

At each selected off-road or roadside location, one or two of the coauthors visited the location during the morning hours in May or June of 2007 or 2008. On arrival at the counting station, we established a waypoint using a Garmin Global Positioning System (GPS) unit and listened for three minutes, conducting a count in standard Breeding Bird Survey protocol. (Note: The use of trade or firm names in this publication is for reader information and does not imply endorsement by the United States Department of Agriculture of any product or service.) When a Cerulean Warbler was detected, the observer went to a location directly below the singing male bird, and either 1) established a second GPS waypoint, or 2) noted the distance and measurement error from the counting station as displayed in the GPS unit. We thus avoid the potential additional source of error caused by observer variability in distance estimation (Alldredge et al. 2007). Observers independently registered the birds; when only one of a pair of observers heard the bird, only that individual was credited with an observation. In cases in which a bird had moved during the interval between initial detection and the observer reaching its location, we did not record a distance. Such occasions were rare, in only 4 of 204 observations were we unable to record a distance. While we did not make specific note of bird movements between detection and distance measurement, such movements beyond minor movements within the same tree, were also rare.

Radial distance measures were calculated by distances between waypoints, or directly as the recorded distance made in the field. Each distance was identified by its type, off-road or roadside, the date, time, and the observer(s) who recorded it.

Statistical Analyses

The set of radial distances recorded in this way was subjected to Multiple Covariate Distance Sampling analysis in Program Distance (Thomas et al. 2005). *A priori* models were established to evaluate appropriate modeling functions, in which data were fitted to half-normal distribution function with cosine adjustment or as hazard-rate function with a polynomial adjustment. We wished to test the null hypotheses that neither observer nor type of registration had an effect on effective detection distance of Cerulean Warbler. We further wished to test the null hypothesis that effective detection distance of Cerulean Warbler did not differ from the 125 m posited by Rich et al. (2004). We used 2nd order AIC corrected for small sample sizes (AIC_c) as our criterion to evaluate models in the candidate set, using AIC differences (ΔAIC_c) and Akaike weights (w_i) to make the comparisons. Upon selection of appropriate model from this set using information theoretic approaches, further evaluations were conducted to identify potential improvements in models when observer and type of registration were included as covariates in the models. For covariates that improved the null, constant detection distance model, individual analyses of these factor combinations were further conducted to produce covariate-specific estimates of effective detection distance.

All analyses were conducted in Program Distance and evaluated using information theoretic methods listed above. Significance level was set at $\alpha = 0.10$ to evaluate goodness of fit tests, given the modest sample sizes achieved. Our test of the null hypothesis that effective detection distance of Cerulean Warbler did not differ from the 125 m posited by Rich et al. (2004) was conducted by assessing whether 125 m fell within the 95% confidence interval around the mean detection distance determined by the various models. When it did not, we rejected the null hypothesis.

RESULTS

We assembled 204 individually measured radial detection distances for Cerulean Warblers in Tennessee in this project (Table 1), approximately equally divided between roadside and off-road detections. Among several models to evaluate the detection distance, each fit the data well (Table 1), with non-significant probability of the model values differing from those observed. The best model for evaluating the effective detection distance was the half-normal approximation, without cosine adjustments (Table 2). An alternative formulation with hazard-rate function produced a model with a ΔAIC_c value more than two units higher than the half-normal function. Neither observer nor type of registration contributed significantly to improving the fit of the model function to the distance data; including observer did improve the AIC_c above the constant model, but the improvement was within two units of AIC_c and the models can thus be considered to be equivalent.

Effective detection distances for Cerulean Warbler in Tennessee resulted in estimates that varied from 88–104 m depending upon observer and registration type (Table 2). The best-supported model, in which observer effects were included in addition to the half-normal functional form, produced an estimate of effective detection distance of 94 m. The constant model,

TABLE 1. Comparison of models of distribution of 204 detection distances for Cerulean Warblers measured in Tennessee, 2007–2008.

Model for Detection Distance	K [a]	ΔAIC_c [b]	AIC_c [c]	w_i [d]	P [e]
Half normal with cosine, Observer	3	0.00	2099.24	0.33	>0.5
Half normal with cosine [constant model]	1	0.40	2099.64	0.27	>0.5
Half normal with cosine, Registration type, Observer	4	1.31	2100.55	0.17	>0.5
Half normal with cosine, Registration type	2	1.58	2100.82	0.15	>0.4
Hazard-rate with polynomial	5	2.93	2102.17	0.08	>0.4

[a] Number of parameters.
[b] $\Delta AIC_c = AIC_{ci} - \min AIC_c$.
[c] $AIC_c = -2 \log L + 2K + 2K(K + 1) / (n - K - 1)$.
[d] $w_i = \exp[-\{\Delta AIC_{ci} / 2\}] / \Sigma \exp[-\{\Delta AIC_{ci} / 2\}]$.
[e] Goodness-of-Fit Probability of modeled function to original data, evaluated with Cramer von Mises tests.

TABLE 2. Radial distances of Cerulean Warblers detected in roadside and off-road counts by three observers in Tennessee, 2007–2008

			Field Measurements		Model Results[a]		
Count type	Observer	Sample size (n)	Mean distance (m)	Standard error (m)	Effective detection distance (m)	Lower 95% confidence limit (m)	Upper 95% confidence limit (m)
Off-road	CGS	23	72.96	6.80	90	66	122
	MJW	33	79.33	6.26	101	79	129
	PBH	44	89.07	7.26	109	93	127
	Any	100	82.15	4.13	95	86	106
Roadside	CGS	21	79.52	6.04	101	68	148
	MJW	70	91.31	5.90	104	94	116
	PBH	13	71.61	13.04	88	67	118
	Any	104	86.47	4.49	98	90	107
Any	CGS	44	76.09	4.55	94	74	119
	MJW	103	87.47	4.50	99	91	108
	PBH	57	85.08	6.36	103	90	118
Total		204	84.35	3.05	94	88	101

[a] Values presented result from models calculated in Program Distance with the appropriate covariates specified and using the half-normal function. For example, results for the Count Type=Off-Road, Observer=MJW row indicate a model in which analysis was confined to all Off-Road observations made by MJW.

in which no effects beyond the parameters of the half-normal form were included, was virtually equivalent to that best-supported model. The constant model produced an effective detection distance of 95 m. All estimates of effective detection distance included 100 m in the 95% confidence interval; only estimates based upon 44 or fewer observations included 125 m in the 95% confidence interval. We present the descriptive results of all the *a priori* models we developed so that the modest variations in effective detection distance can be seen (Table 2).

DISCUSSION

Our data do not support the assumption in Rich et al. (2004) that the effective detection distance for Cerulean Warbler is 125 m. A more appropriate detection distance is 95 m (Table 2), or 100 m, a value included in the 95% confidence interval of all of our estimates. Blancher et al. (2007) indicated that estimates of effective detection distance presented in Rich et al. (2004) are intended to be conservative or robust. They further indicate that an order of magnitude resolution is appropriate for the use of the population size estimates produced by their methods. Inasmuch as this was a study of a single species, in which we attempted specifically to register Cerulean Warblers, our estimate of effective detection distance is likely also conservative relative to one developed during counts in which the intent was to register all. Thus, the actual effective detection distance applicable to the BBS data used by Rich et al. (2004) may be even shorter than our estimate.

We found no effect of type of registration, roadside or off-road, on effective detection distance for Cerulean Warbler in this study, suggesting that Breeding Bird Survey methods may provide an adequate representation of detection distance within habitats. Effect of difference among observers, while representing an improvement in AIC_c over the constant detection distance model, did not meet the criterion of an improvement of two AIC_c units over the constant detection distance model. Thus, in this study, observer effects were minor or not significant.

Our result, that the effective detection distance of Cerulean Warbler is 100 m rather than 125 m, indicates that the population estimate of this species provided in Rich et al. (2004) of 560 000 may be an underestimate. The difference between the assumed 125 m and our 100 m effective detection distance is a reduction in sampled area of 36%. Applying this reduction in area to the estimate in Rich et al. (2004) results in a population estimate of 875 000 (range: 858 000–1 130 000, given 94 m estimate with 88–101 m CI). Our estimate, 100 m, is one that is sufficient for some variation in observers and for different areas in bottomland and upland forest in Tennessee. The study areas we chose in middle and west Tennessee represent a range of topography and vegetation composition reflective of Cerulean Warbler habitats in that state, and perhaps elsewhere as well. Nevertheless, our estimated effective detection distance should not be considered to apply to the entire breeding range of the species without further specific evaluation in additional areas.

Thogmartin (2006 unpublished ms. http://www.fws.gov/midwest/Eco%5FServ/soc/birds/cerw/cerw06rapp5c.pdf; 27 March 2009) estimated the probability of a 90% decline in Cerulean Warbler populations at perhaps 90% within a century of the 1995 estimate of population at 560 000. His work further suggested that if the population was assumed to be 50% higher in 1995 than the 560 000 value given by Rich et al. (2004), the probability of population reduction would be reduced, and the estimated time to reach the 90% probability of a 90% decline would be more than a century. Based upon the findings reported here, which imply that the 1995 population was perhaps 50% higher than the Rich et al. (2004) estimate, we suggest that the period of time in which conservation actions can be applied to reverse the declines in the species numbers is longer than previously estimated.

CONCLUSIONS

We tested the assumed effective detection distance for Cerulean Warbler presented in the North American Landbird Conservation Plan (Rich et al. 2004) and found it to be closer to 100 m than the assumed 125 m. We found no difference between the effective detection distance recorded on off-road versus roadside point counts in Tennessee, and only a small effect of observer variability on the estimated effective detection distance. We suggest that the time for applying conservation action to maintain and increase populations of this species of conservation concern, though finite, is considerably longer than previously supposed.

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