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A COMPARISON OF THREE COUNT METHODS FOR MONITORING SONGBIRD ABUNDANCE DURING SPRING MIGRATION: CAPTURE, CENSUS, AND ESTIMATED TOTALS

Erica H. Dunn, David J. T. Hussell, Charles M. Francis, and Jon D. McCracken

Abstract. We compared long-term trends (1984–2001) based on three types of spring migration count data, from the three migration monitoring stations at Long Point Bird Observatory (southern Ontario), for 64 species. The three count methods consisted of daily capture totals from banding, sightings from a daily 1-h count on a fixed route ("census"), and "estimated totals" (ETs). The latter were estimates of birds detected in each study area each day, based on results from banding, census, and unstandardized "other observations." In the majority of species, ET annual indices were significantly positively correlated with both banding and census indices. Banding was not standardized, and variance of annual banding indices was higher than for other count methods, but trends based on banding alone were similar in magnitude to trends from census alone. Relative to trends based on banding or census alone, ET trends were positively biased, possibly as a result of change in estimation methods over time. Nonetheless, because ETs combine data from a variety of count methods, more species can be monitored, with greater precision, than by using one count method alone. Comparison of trends among stations suggested an influence of habitat change at one location. Biases should be minimized with strict standardization of all component count methods, adherence to a clear protocol for ETs, and management of vegetation to prevent systematic habitat change.

Key Words: banding, Breeding Bird Survey, census, estimated totals, habitat bias, migration monitoring, population trend, trend analysis.

Standardized counts of migrating birds can be used to calculate population trends, which have been shown to correlate with trends from the Breeding Bird Survey (BBS; Hussell et al. 1992, Dunn and Hussell 1995, Dunn et al. 1997, Francis and Hussell 1998). Recommended guidelines for migration counting (Hussell and Ralph 1998) state that each monitoring station should select the count method that is most suitable for the location, which may include daily banding, route surveys, counts of birds moving past a fixed point, or some combination of count methods. Different counting techniques may be more suitable for certain types of migratory species, and magnitude of counts will differ among methods, but as long as count protocol at any station is followed consistently, trends should be the same regardless of the type of migration count. However, this assertion has not previously been tested.

Here we present results of separate trend analyses for different count methods from the Long Point Bird Observatory (LPBO), in southern Ontario. At each of three stations (all within 30 km of one another), there was daily banding and a daily "census" (approximately 1-h survey of birds along a fixed route). In addition, records were kept of all birds detected during these and other activities in the day ("other observations"). At the end of the day, all personnel gathered to agree on "estimated totals" (ETs). These were estimates of the total number of individuals detected in the defined study area that day, based on all available data. We estimated trends based on banding totals, census counts, and ETs separately, then compared them with each other and with trends from BBS.

Whatever methods are selected for migration counts, it is important to use them in a standardized and consistent manner from day to day and year to year, so that variation in counts will not reflect changes in methods (Ralph et al. *this volume a*). At Areas 1 and 2 (the two stations on the Long Point peninsula), early successional dune habitat consists of constantly shifting shorelines and vegetation patches, which has required periodic change in net locations. Moreover, the number of nets that can be operated safely, and the effectiveness of the nets, varies with wind strength at these exposed locations. Areas 1 and 2 each had a Heligoland trap (Woodford and Hussell 1961) that was often used in addition to nets, or in place of nets when weather precluded netting. Banding at Area 3 (the third station, at the mainland end of Long Point) was more standardized in net placement, but not necessarily in number of nets operated or daily operating hours. The census, on the other hand, has always been conducted in a consistent manner at all stations. A comparison of trends based on census or banding alone should therefore allow us to examine the effect of standardization in banding on population trends. Comparison with ET trends should indicate the relative importance of each survey method for particular species, and show whether combining data from different count methods adds to the effectiveness of monitoring.

METHODS

Data were collected from mid-April to early June, 1984–2001, at LPBO's three stations on Long Point, on the north shore of Lake Erie. For each of 64 species of common migrants (Table 1), we calculated annual indices for three data sets (daily banding totals, census, and ETs) for each station separately, and in a composite analysis that produced indices for all stations together.

Banding data were the raw daily banding totals (new captures only), unadjusted for effort. Ideally, capture totals should be corrected for effort either through calculating birds per unit effort (e.g., net-h, trap-h; or, for Heligoland traps, trap-drives), or through including effort as a covariate. However the effort data have not been computerized, and extraction was ruled out for this analysis because time and cost were prohibitive. Even if the data were available, there is no simple way of combining effort-corrected results from each type of capture method.

The Long Point "census" was not a true total count, but rather a daily survey that recorded all birds identified by sight or sound along a fixed route that wound throughout the study area. The census was usually (but not always) done by one observer. Personnel often changed from day to day, and nearly always from year to year, so long-term trends should not be affected by systematic observer bias. Each walk lasted about 1 h and was conducted in early or mid-morning. The route at Area 1 was altered in 1986 and the route at Area 2 in 1988 to accommodate loss of area due to erosion, but otherwise the routes remained fixed.

"Other observations" consisted of sightings within the defined study area additional to census, but there was no standardization of the amount of time expended or number of observers contributing. As noted above, the "defined study area" was altered somewhat at Area 1 in 1986 and at Area 2 in 1988.

ETs were derived jointly at each day's end by all participants. The ETs were intended to be carefully considered estimates of numbers detected in the study area that day, based on banding, census, and other observations. Double-counting was avoided where possible by taking into account numbers retrapped and likelihood that independent sightings were actually of the same birds. The ET procedure was devised in part to overcome the problems posed by a banding program that could not be fully standardized, and the census was intended to provide consistent daily input. ETs were the best estimate by personnel at the station of birds detected each day, regardless of variation in effort put into the various component counts.

Data were included in analyses only for dates within a species-specific time period judged to constitute the spring migration season of each species at Long Point (Hussell et al. 1992). Annual indices were calculated from a regression procedure designed to assign variability in daily counts to date, weather, moon phase, and year (Francis and Hussell 1998). Composite analyses (designed to produce indices combining data from all three stations) also included dummy variables for station, and for interactions between station and all other variables except those for year. Analysis methods are described in detail elsewhere (Hussell et al. 1992, Francis and Hussell 1998), and the following gives only a brief overview.

The dependent variable in the regression analyses was log (daily count + 1), in which the "daily count" was either the daily number of newly-banded birds, the number recorded on the daily census, or the daily estimated total (i.e., the analyses were run three times for each species). The constant was added to allow transformation of zeros, and 1 was chosen because it is the minimum change that can occur in daily counts. The log-transformed daily count was the dependent variable in a regression that included independent variables for year (dummy variables for each year except for one reference year; e.g., Y79 = 1 if the year was 1979, otherwise Y79 = 0), date (first through fifth order day terms), first and second order moon phase variables (days from nearest new moon and its square), and 12 weather variables. Weather variables were constructed using data from Erie, Pennsylvania (40 km south of the study locations), as detailed in Francis and Hussell (1998), and included daily values for horizontal visibility, cloud cover, first and second order terms for temperature difference from normal, and first and second order terms of four wind variables. Annual abundance indices were calculated from the coefficients of the dummy variables for year that were estimated in the regression. The annual abundance index was the adjusted mean for year plus one-half of the error variance of the regression (so the corrected index in the original scale represented an estimate of the mean rather than of the median; see references in Hussell et al. 1992), back-transformed to the original scale. The adjusted mean for year represented the mean of the transformed daily counts under standardized conditions of day, weather, and moon. The annual abundance indices therefore represented the estimated numbers of birds that would be counted each year on the same average date in the season, under average weather and moon conditions.

Trends were calculated as the slope from the weighted linear regression of log-transformed annual indices on year. Weights were proportional to the number of daily counts in the year represented by the index.

We performed bivariate correlations between annual banding and census indices to determine level of correspondence. To determine whether banding and census had independent effects on ET, we performed multiple regressions for each species, with log-transformed ET annual index as the dependent variable, and log-transformed banding and census indices as independent variables.

To detect difference in trends according to count method, we conducted species-specific analyses of

TABLE 1. RELATIONSHIPS AMONG ANNUAL INDICES (1984–2001) FROM BANDING AND CENSUS (DATA FROM THREE STATIONS COMBINED) AT LONG POINT, ONTARIO

		Contribution to ET[b]		
Species	Banding-census r[a]	Census	Banding	R^{2} [c]
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	0.66**	***		0.63
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	0.92***	***		0.93
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	0.74***	***		0.75
Northern Flicker (*Colaptes auratus*)	0.75***	***		0.83
Eastern Wood-Pewee (*Contopus virens*)	0.35	**	+	0.53
Yellow-bellied Flycatcher (*Empidonax flaviventris*)	0.41+	*	***	0.76
Least Flycatcher (*E. minimus*)	0.35		***	0.71
Eastern Phoebe (*Sayornis phoebe*)	0.77***	***	*	0.89
Great Crested Flycatcher (*Myiarchus crinitus*)	-0.04	**		0.28
Blue-headed Vireo (*Vireo solitarius*)	0.90***	*	**	0.90
Warbling Vireo (*V. gilvus*)	0.29	***		0.85
Philadelphia Vireo (*V. philadelphicus*)	0.67**		**	0.72
Red-eyed Vireo (*V. olivaceus*)	0.62**	+	***	0.73
Brown Creeper (*Certhia americana*)	0.85***		**	0.85
House Wren (*Troglodytes aedon*)	0.44+	***	***	0.86
Winter Wren (*T. troglodytes*)	0.76***	***	***	0.94
Golden-crowned Kinglet (*Regulus satrapa*)	-0.28	***	*	0.85
Ruby-crowned Kinglet (*R. calendula*)	0.74***	**	*	0.80
Blue-gray Gnatcatcher (*Polioptila caerulea*)	0.35	***	+	0.73
Veery (*Catharus fuscescens*)	0.59**	**	***	0.89
Gray-cheeked Thrush (*C. minimus*)	0.16	*	***	0.67
Swainson's Thrush (*C. ustulatus*)	0.56*	**	***	0.85
Hermit Thrush (*C. guttatus*)	0.67**		**	0.62
Wood Thrush (*Hylocichla mustelina*)	0.48*	*	***	0.71
American Robin (*Turdus migratorius*)	0.08	***		0.69
Gray Catbird (*Dumetella carolinensis*)	0.88***	**	*	0.91
Brown Thrasher (*Toxostoma rufum*)	0.79***	**		0.75
Tennessee Warbler (*Vermivora peregrina*)	0.81***	*	***	0.88
Nashville Warbler (*V. ruficapilla*)	0.78***	***		0.81
Yellow Warbler (*Dendroica petechia*)	0.73***	***	***	0.97
Chestnut-sided Warbler (*D. pensylvanica*)	0.70**		***	0.69
Magnolia Warbler (*D. magnolia*)	0.47*		***	0.85
Cape May Warbler (*D. tigrina*)	0.82***	**	*	0.86
Black-throated Blue Warbler (*D. caerulescens*)	0.67**		***	0.78
Yellow-rumped Warbler (*D. coronata*)	0.82***	***		0.78
Black-throated Green Warbler (*D. virens*)	0.67**	**		0.60
Blackburnian Warbler (*D. fusca*)	0.43+	*	*	0.55
Palm Warbler (*D. palmarum*)	0.36	***		0.75
Bay-breasted Warbler (*D. castanea*)	0.80***	*	*	0.80
Blackpoll Warbler (*D. striata*)	0.79***	***	**	0.91
Black-and-white Warbler (*Mniotilta varia*)	0.81***	*	+	0.73
American Redstart (*Setophaga ruticilla*)	0.59*		***	0.80
Ovenbird (*Seiurus aurocapilla*)	0.85***	**	***	0.93
Northern Waterthrush (*S. noveboracensis*)	0.79***	**	***	0.93
Mourning Warbler (*Oporornis philadelphia*)	0.33	**	***	0.72
Common Yellowthroat (*Geothlypis trichas*)	0.71**	**	**	0.80
Wilson's Warbler (*Wilsonia pusilla*)	0.20	**	***	0.78
Canada Warbler (*W. canadensis*)	0.34	+	**	0.61
Scarlet Tanager (*Piranga olivacea*)	0.60**	***		0.86
Eastern Towhee (*Pipilo erythropthalmus*)	0.75***	***	+	0.90
Chipping Sparrow (*Spizella passerina*)	0.79***	***	*	0.92
Field Sparrow (*S. pusilla*)	0.55*	**	**	0.76
Vesper Sparrow (*Pooecetes gramineus*)	0.54*	**	+	0.60

TABLE 1. CONTINUED

Species	Banding-census r[a]	Contribution to ET[b]		R^2 [c]
		Census	Banding	
Savannah Sparrow (*Passerculus sandwichensis*)	0.83***	**		0.76
Fox Sparrow (*Passerella iliaca*)	0.63**	***	+	0.85
Song Sparrow (*Melospiza melodia*)	0.77***	*		0.59
Lincoln's Sparrow (*M. lincolnii*)	0.46+	***	***	0.86
Swamp Sparrow (*M. georgiana*)	0.81***	***		0.90
White-throated Sparrow (*Zonotrichia albicollis*)	0.85***		*	0.75
White-crowned Sparrow (*Z. leucophrys*)	0.73***	***	*	0.87
Dark-eyed Junco (*Junco hyemalis*)	0.79***	*		0.55
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	0.68**	***		0.85
Indigo Bunting (*Passerina cyanea*)	0.88***	*		0.76
Baltimore Oriole (*Icterus galbula*)	0.38	***		0.72

[a] Correlation coefficient between annual indices from banding and census.
[b] Significance of partial correlation coefficient in regression of ET indices on indices for banding and census, indicating whether the count method significantly influenced ET independently of the other count method (* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$).
[c] Proportion of annual variation in ET indices explained by census and banding indices (R^2 of regression described in footnote b). All R^2 were significant (symbols not shown).

covariance with count method as the factor and year as covariate. We examined interactions between count method and year. Significant interactions indicated trends that differed in slope.

We compared variability in indices among count methods by calculating variance in the residuals from linear regressions of log-transformed indices on year (thereby removing variability related to long-term trends in the data).

To determine whether trends from different stations or those based on different count methods produced the same magnitude of trend (e.g., comparing the 64 species, trends based on census from Area 1 to those from Area 2), we conducted reduced major axis regression on pairs of trends (Bohonak 2002). If trends from the two sources correspond in magnitude, then the regression results would show an intercept of 0 and a slope of 1.

RESULTS

Analysis of annual indices based on data pooled from all three stations showed that banding and census indices were usually correlated with each other (73% of 64 species). In 35 species, banding and census each had independent influences on annual ET indices, even though banding and census indices were usually correlated with each other (Table 1). In 20 additional species, banding did not add anything to ETs after census had been taken into account, and in 9 species the reverse was true. For these 29 species, the non-contributing count method usually had much lower mean counts than the other, and thus had little influence on the ET indices whether or not the banding and census indices were correlated with each other. A few species had very low R^2 values (most notably Great Crested Flycatcher [scientific names in Table 1]), indicating that ETs were heavily influenced by observations other than those from banding and census. Results were similar when analysed for each station separately.

Variance of detrended annual indices based on banding was highest at Area 1, lower at Area 2, and lowest at Area 3 (Table 2), but there were no significant differences. Variability of indices based on census was more similar among stations, and ET indices were the least variable, but for all three count methods, variability was lowest at

TABLE 2. COMPARISON OF VARIANCE IN DETRENDED ANNUAL INDICES OVER 17 YEARS FOR DIFFERENT COUNT METHODS AND STATIONS AT LONG POINT, ONTARIO

Station	Mean variance ± SD[a] of indices based on		
	Banding	Census	ET
Area 1	0.47 ± 0.26	0.31 ± 0.21	0.21 ± 0.16
Area 2	0.33 ± 0.25	0.29 ± 0.23	0.22 ± 0.19
Area 3	0.17 ± 0.16	0.21 ± 0.16	0.13 ± 0.07
All stations combined	0.12 ± 0.13	0.11 ± 0.08	0.09 ± 0.05

[a] Mean and SD across species of individual species' variance of detrended annual indices.

TABLE 3. COMPARISON OF TRENDS FROM 1984–2001 BASED ON INDICES FROM DIFFERENT COUNT METHODS AT LONG POINT, ONTARIO

Area	Count methods compared	Slope	Intercept	R^2
1	Census vs. band	0.85*	-0.57	0.56
	ET vs. band	0.70**	1.10**	0.73
	ET vs. census	0.83**	1.58**	0.83
2	Census vs. band	1.10	-0.81	0.29
	ET vs. band	0.90	1.40**	0.53
	ET vs. census	0.82**	2.07**	0.70
3	Census vs. band	0.78*	-0.78	0.09
	ET vs. band	0.76**	0.54	0.35
	ET vs. census	0.95	1.36**	0.63
All	Census vs. band	1.02	-0.34	0.51
	ET vs. band	0.93	1.16**	0.64
	ET vs. census	0.91*	1.46**	0.86

Notes: Slope, intercept, and R^2 from reduced major axis regression of the trends from the two count methods being compared (Bohonak 2002). Significance levels are for test of null hypothesis that slope is 1.0, and intercept is 0 (* = $P < 0.05$, ** = $P < 0.01$).

Area 3. Regardless of count method, variability was considerably reduced when indices were based on data from all three stations combined.

Trends from pairs of count methods were compared within stations, using reduced major axis regression. In Table 3, an intercept >0 indicates a tendency to a positive bias in the first count method relative to the second method in each pair. In seven of eight comparisons, ET trends were positively biased relative to banding and census. These eight comparisons also showed slopes <1 (significant in five cases), indicating that the positive bias was less in species with increasing trends than in those with decreasing trends (Table 3, Fig. 1). By contrast, census showed little bias relative to banding, although at two stations the slopes of the relationships were significantly <1, indicating a tendency to a negative bias in census relative to banding in increasing species and the opposite effect in decreasing species (Table 3).

A similar analysis compared trends within count methods between pairs of stations (Table 4). Trends at Area 3 were strongly more negative, for all count methods, relative to trends at Areas 1 and 2 (as shown by the negative intercepts). However, slopes tended not to differ between stations (seven of nine comparisons).

DISCUSSION

Lack of standardization in banding added variability to annual indices. Variability was highest at the station with least standardization (Area 1), and lowest where netting effort was most uniform (Area 3; Table 2). Increased variability reduces trend precision, such that it will take longer to detect a significant population change. However, increased variance of banding indices did not have a detectable effect on magnitude of estimated trends, which showed the same relationship to census trends at all three stations (Table 3).

The ET procedure incorporates data from census as well as from banding (Table 1), and ET indices were less variable than banding or census indices alone (Table 2). ETs therefore performed their intended function of removing some of the variability from unstandardized banding effort and adding information from other count methods.

Compared to banding and census, ETs tended to be positively biased (Fig. 1). Although we cannot be sure which method best represents actual population trends, there are several reasons to suspect that ETs might be positively biased. First, there appears to have been a change in the way ETs were estimated, starting in about 1993, with observers becoming less conservative in their estimates (E. Dunn et al., unpubl. data). In addition, there may have been an increase over time in the number of personnel, and longer hours spent in the field. We were unable to correct for variable effort in our analyses, and effort-correction is in any case an imperfect and time-consuming solution, particularly when many types of effort are combined. However, additional work could be done to determine the relative importance of these sources of bias. Regardless of the source of bias in historical data at Long Point, bias in trends from other stations or from Long Point in future can be minimized by ensuring that every aspect of data

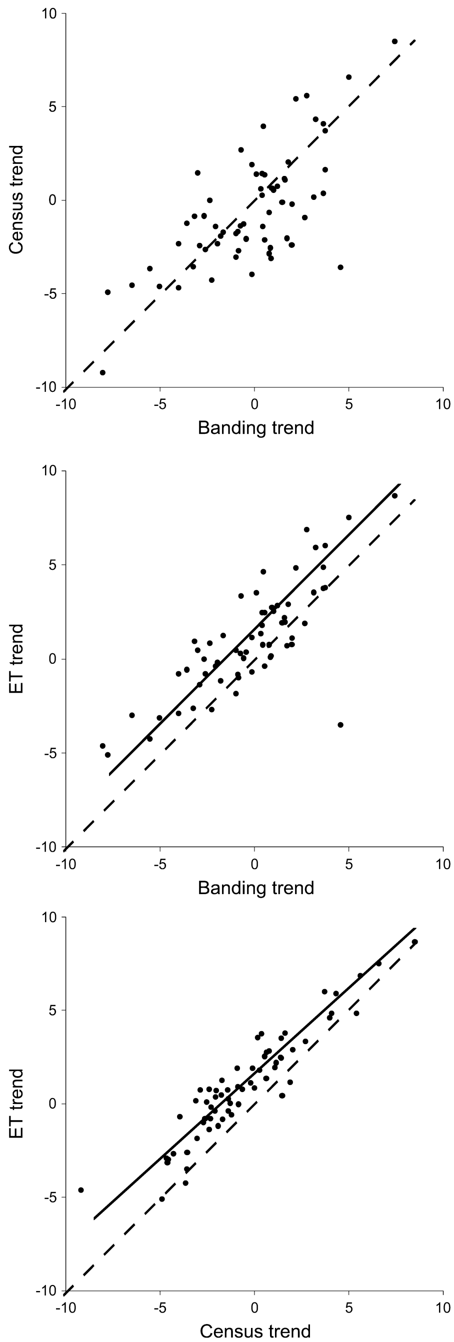

FIGURE 1. Comparison of population trends at Long Point, Ontario, based on different data sources (data pooled from all stations). ET trends were positively biased relative to trends based on banding or census alone. Dashed line indicates one-to-one correspondence between trends; solid line shows fit according to reduced major axis regression (shown only if different from the dashed line).

TABLE 4. COMPARISON OF TRENDS FROM 1984–2001 BASED ON INDICES FROM THREE DIFFERENT COUNT AREAS AT LONG POINT, ONTARIO

Count method	Areas compared	Slope	Intercept	R^2
Banding	2 vs. 1	0.75**	-0.41	0.22
	3 vs. 2	1.08	-3.19**	0.12
	3 vs. 1	0.80	-3.79**	0.03
Census	2 vs. 1	0.97	-0.73	0.24
	3 vs. 2	0.84	-2.72**	0.24
	3 vs. 1	0.74**	-3.42**	0.24
ET	2 vs. 1	0.95	0.01	0.30
	3 vs. 2	0.96	-3.35**	0.25
	3 vs. 1	0.91	-3.58**	0.43

Notes: Slope, intercept, and R^2 are from reduced major axis regression of the trends from the two areas being compared (Bohonak 2002). Significance levels are for test of null hypothesis that slope is 1.0, and intercept is 0 (* = $P < 0.05$, ** = $P < 0.01$).

collection is strictly standardized, as recommended by Ralph et al. (*this volume* a).

We found clear evidence of station differences in population trends. We have no reason to suspect that the strongly more negative trends at Area 3, relative to trends at the other two stations, were related to station differences in data collection. One possible explanation is differential habitat change among the three stations. Area 3 is a small woodlot surrounded by marsh and cottage. The vegetation at this station, especially the trees, grew steadily taller throughout the study period and understory was reduced. Many of the species for which the trend at Area 3 was the lowest (most negative) of the three stations, both for banding and census, are large and conspicuous. These species would probably have been detected if present, so we suspect they do not use the location now as often as in the past (e.g., Northern Flicker, Great Crested Flycatcher, nearly all thrushes, Brown Thrasher, Gray Catbird, Rose-breasted Grosbeak, Scarlet Tanager, Baltimore Oriole). However, another 23 species with their lowest trends at Area 3, made up mostly of warblers and vireos, could have been present but detected and captured in mist nets with lower probability as the canopy grew higher and more dense. In contrast to Area 3, Areas 1 and 2 are maintained at relatively early successional stages by storms and shifting of dunes. Although habitat at these two areas is certainly not constant, change appears to be less directional over time.

It is often stated in the migration monitoring literature that habitat change could bias population trends, but this is often ignored when study locations are selected and results are being interpreted. The difference between trends at Area 3 and the other two sites at Long Point suggest that habitat effects could be substantial, and emphasizes the importance of having an effective habitat management protocol for long-term studies.

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