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# METHODOLOGICAL STUDIES OF BREEDING BIRD SURVEYS IN NORTH AMERICA

A. R. SEN[1]

ABSTRACT.—Surveys are being annually conducted in U.S.A. and Canada to provide management with reliable data to detect and measure both short term (annual) and long term changes in abundance of non-game breeding birds. The data are collected by cooperators who make road side counts on predetermined stops on predetermined routes.

This paper deals with the methodological aspects of (1) estimating the density of birds of a given species and its error in a given region during a year (2) detecting short term or annual change in population density and (3) measuring relative abundance of a species between two years for a region based on the same sample points and the same routes covered during the period. The analysis was based on data for the Maritime Provinces of Canada.

It is shown that for some clumped species the estimated number of birds per route was highly skewed and the number of routes selected for sampling in a region was not adequate enough to ensure normality of mean number of birds per route. Logarithmic transformation of the data ensured approximate normality; it resulted in some gain in efficiency of the mean but considerable gain in efficiency of the variance.

For a few species, the estimate of relative change in number of birds per route was subject to high error and the statistical tests failed to detect real difference between the years. In such cases, tests based on transformed data proved more amenable to statistical treatment.

Surveys are being annually conducted in the U.S.A. and Canada for detecting and measuring changes in abundance of non-game breeding birds at the height of the breeding season. The data are collected by cooperators who make road-side counts on predetermined stops on predetermined routes according to a specified sampling scheme.

The methods which are being currently used are not sensitive and reliable enough to detect changes in a region for a number of species for which the distributions are highly skewed; also the sample size is not large enough to ensure normality of the mean. The present paper deals with the methodological aspects of: (1) estimating the abundance of birds of a given species and its error in a region during a year; (2) detecting differences in abundance among species during a year with a view to determining relative species abundance, annual changes in abundance for a particular species based on the same sample points in the same routes covered during the period; and (3) measuring relative change in abundance of a species in a region between two years to find how these vary for common and uncommon species. The average number of birds measured per route in a region will be defined as abundance for the region.

The analysis is based on data for the Maritime provinces for the two years 1971 and 1972.

## DESIGN OF THE SURVEYS

The design of the breeding bird surveys is based on a stratified random sample of roadside counts (Robbins and Van Velzen 1967, 1969; Erskine 1970, 1973; Smith 1973). For operational convenience each degree block of latitude (8.5 km × 112.7 km each) was chosen as stratum. Within each stratum several transects or routes and the compass directions were chosen at random and without replacement. A point was first chosen at random within a degree block as the intersection of latitude and longitude determined with the help of a pair of random numbers. Next, the point which lay on a good road nearest the chosen point was used as the starting point of the route. Where there was no road in the immediate neighborhood, the chosen point was selected as the closest recognizable landmark on a passable route. The sampling is done by volunteer observers who travel along the selected routes making stops at regular intervals. All birds heard or seen at each of 50 three minute stops at 0.8 km (one-half mile) intervals along the routes are counted and recorded by observers. As far as practicable, the same observers were used on the same stops and on the same routes during the two years 1971–72.

## RESULTS

### ESTIMATES OF SKEWNESS—ITS EFFECT ON DENSITY ESTIMATES

The average number of birds counted per route for some of the common and uncommon species in the Maritime Provinces during 1971 and 1972 was used to estimate departures from normality by skewness ($g_1 = m_3/m_2^{3/2}$) and kurtosis ($g_2 = m_4/m_2^2 - 3$) where

$$m_2 = \Sigma(y_i - \bar{y})^2/n;\; m_3 = \Sigma(y_i - \bar{y})^3/n;$$
$$m_4 = \Sigma(y_i - \bar{y})^4/n,$$

$y_i$ is the number of birds seen or heard along the $i$th route, $n(=41)$ is the number of comparable routes covered during the years.

The estimates of average number of birds counted per route, their standard error, skewness and kurtosis for the species are presented

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[1] Migratory Birds Branch, Canadian Wildlife Service, Ottawa, Ontario, K1A 0E7 Canada.

TABLE 1

ESTIMATES OF AVERAGE NUMBER OF BIRDS PER ROUTE, STANDARD ERROR, SKEWNESS ($G_1$) AND KURTOSIS ($G_2$) IN THE MARITIMES DURING 1971 AND 1972[a]

| | 1971 | | | | 1972 | | | |
|---|---|---|---|---|---|---|---|---|
| Species | Average number of birds per route | Standard error | $g_1$ | $g_2$ | Average number of birds per route | Standard error | $g_1$ | $g_2$ |
| Common Snipe (*Capella gallinago*) | 5.32 | 1.02 | 1.60* | 2.11** | 4.93 | 0.77 | 0.76* | −0.74* |
| Herring Gull (*Larus argentatus*) | 37.12 | 13.26 | 3.73** | 15.18** | 54.41 | 25.74 | 5.70** | 34.58** |
| Least Flycatcher (*Empidonax minimus*) | 5.12 | 0.69 | 1.48* | 2.99** | 5.04 | 0.73 | 1.36* | 2.71** |
| Tree Swallow (*Iridoprocne bicolor*) | 21.21 | 2.71 | 1.68* | 3.54** | 18.73 | 2.75 | 2.48** | 8.88** |
| Yellow-bellied Sapsucker (*Sphyrapicus varius*) | 8.66 | 2.28 | 2.86** | 10.18** | 5.56 | 1.39 | 2.00** | 3.37** |
| Bank Swallow (*Riparia riparia*) | 24.15 | 6.50 | 2.17** | 4.24** | 18.05 | 5.25 | 2.95** | 9.43** |
| Blue Jay (*Cyanocitta cristata*) | 5.22 | 1.41 | 4.06** | 20.07** | 4.10 | 0.75 | 1.90** | 4.79** |
| Common Crow (*Corvus brachyrhynchos*) | 34.49 | 4.34 | 1.80** | 3.95** | 38.49 | 5.32 | 1.38* | 1.25* |
| Robin (*Turdus migratorius*) | 65.29 | 4.04 | 0.19 | −0.63 | 60.73 | 4.30 | 0.37 | −0.30 |
| Starling (*Sturnus vulgaris*) | 44.63 | 5.98 | 1.06* | 1.00 | 44.27 | 6.10 | 1.00* | 0.97 |
| Common Grackle (*Quiscalus quiscula*) | 24.66 | 6.93 | 3.81** | 15.54** | 26.05 | 7.22 | 3.86** | 15.91** |
| White-throated Sparrow (*Zonotrichia albicollis*) | 53.80 | 5.10 | 0.95* | 0.41 | 57.80 | 5.39 | 1.18* | 0.66 |

* $P < 0.05$.
** $P < 0.01$.
[a] Total number of comparable routes = 41.

in Table 1. For tests of significance of skewness and kurtosis for sample size $n = 41$, the one-tailed five percent and one percent significance levels of $g_1$ computed from a more accurate approximation given in Snedecor and Cochran (1977) may be employed. It is seen that the distribution of the numbers of birds was positively and highly skewed for almost all the species during both the years excepting Robin, Starling and White-throated Sparrow. This has the effect of increasing the variance of the annual index (mean count per route) and decreasing its precision. Owing to the marked positive skewness, the number of routes selected in the Maritimes is not large enough to ensure normality. Thus, tests based on normal theory will not be valid and tend to be less efficient and sensitive for detecting differences.

## SAMPLE SIZE TO ENSURE NORMALITY

The question arises, "How large must $n$ (the number of routes sampled within the Maritimes) be, so that the normal approximation is accurate for computing confidence limits of the annual indices (mean counts per route)?" For populations in which the principal deviation from normality consists of marked positive skewness and kurtosis, we have

$$n > 25G_1^2 - 1.64G_2 \qquad (1)$$

where $G_1$ and $G_2$ are Fisher's measure of skewness and kurtosis in the population and are estimated by $g_1$ and $g_2$, so that a 95% probability statement will be wrong not more than six percent of the time. In a personal correspondence Prof. Cochran reported that the above result (1) is due to Dr. Glen Bartsch and was derived later than his own (Cochran 1977:42) which assumes only marked skewness in the population.

For 9 of the 12 species considered in the study (excepting Robin, Starling and White-throated Sparrow) the sample size (number of routes) for estimating the abundance of birds during a year was less than that needed for the normal approximation. Hence for these species, the abun-

TABLE 2

Estimates of Average Log ($y + 1$), Where $y$ is the Number of Birds Counted on a Route, Standard Error, Skewness ($g'_1$) and Kurtosis ($g'_2$) in the Maritimes During 1971 and 1972[a]

| Species | 1971 | | | | 1972 | | | |
|---|---|---|---|---|---|---|---|---|
| | Average log ($y + 1$) | Standard error | $g'_1$ | $g'_2$ | Average log ($y + 1$) | Standard error | $g'_1$ | $g'_2$ |
| Common Snipe | 0.58 | 0.07 | 0.19 | −1.14* | 0.59 | 0.07 | −0.12 | −1.38** |
| Herring Gull | 0.91 | 0.12 | 0.48 | −0.77 | 1.02 | 0.13 | 0.23 | −0.86 |
| Least Flycatcher | 0.67 | 0.05 | −0.51 | −0.15 | 0.65 | 0.06 | −0.01 | −0.96* |
| Tree Swallow | 1.23 | 0.05 | −0.12 | −0.30 | 1.16 | 0.06 | 0.00 | −0.43 |
| Yellow-bellied Sapsucker | 0.62 | 0.09 | 0.50 | −0.93* | 0.48 | 0.08 | 0.59 | −1.09* |
| Bank Swallow | 0.85 | 0.12 | 0.36 | −1.12* | 0.80 | 0.10 | 0.34 | −0.75 |
| Blue Jay | 0.56 | 0.07 | 0.55 | −0.05 | 0.54 | 0.06 | 0.18 | −0.99* |
| Common Crow | 1.40 | 0.08 | −1.24* | 2.03* | 1.40 | 0.07 | −1.58** | 3.99** |
| Robin | 1.78 | 0.03 | −0.75 | 0.29 | 1.74 | 0.03 | −0.73 | 0.29 |
| Starling | 1.44 | 0.08 | −1.11** | 0.99 | 1.37 | 0.09 | −1.02** | 0.19 |
| Common Grackle | 1.09 | 0.08 | 0.46 | −0.01 | 1.13 | 0.08 | 0.28 | 0.56 |
| White-throated Sparrow | 1.65 | 0.05 | −1.33** | 3.80** | 1.69 | 0.04 | −0.29 | 0.72 |

* $P < 0.05$.
** $P < 0.01$.
[a] Total no. of comparable routes = 41.

dance of birds was estimated with lesser confidence unless sample sizes were increased considerably, which is not generally practicable nor feasible since it would be unwise to put pressure on the volunteer observers who are responsible for the collection of data.

### LOG-TRANSFORMATION

When the data were transformed by taking $z = \log_e(y + 1)$ where $y$ is the number of birds counted on a route, the distribution of $z$ was approximately normal. Table 2 presents the picture using $\log_{10}(y + 1)$ instead of $\log_e(y + 1)$, which, as may be seen, will not affect our conclusions. Only 2 out of the 12 species (Table 2) showed significant skewness and kurtosis in both the seasons. In all cases, the number of routes selected was large enough (result (1)) to ensure normality of the mean on the logarithmic scale. Also, the estimates of the mean in the transformed scale were more precise having lower coefficient of variation (c.v.) to detect differences in the abundance of birds among species than on the original scale. Thus, with direct measurements (Table 3), there was no significant difference between the average number of Herring Gulls and Tree Swallows counted during 1971 (in fact the mean number of Herring Gulls appeared to be higher) but on the logarithmic scale, the average number of Tree Swallows counted was significantly higher than the number of Herring Gulls as shown by the 90% con-

TABLE 3

Ninety % Confidence Interval of Average Number of Birds Counted per Route ($\bar{y}$) and Average Log ($y + 1$) for the Different Species in the Maritimes During 1971 and 1972[a]

| Species | $\bar{y}$ | | Average log ($y + 1$) | |
|---|---|---|---|---|
| | 1971 | 1972 | 1971 | 1972 |
| Common Snipe | 3.60– 7.04 | 3.63– 6.23 | 0.47–0.70 | 0.48–0.71 |
| Herring Gull | 14.79–59.45 | 11.06–97.76 | 0.70–1.11 | 0.81–1.24 |
| Least Flycatcher | 3.96– 6.28 | 3.81– 6.27 | 0.58–0.76 | 0.55–0.74 |
| Tree swallow | 16.65–25.77 | 14.10–23.36 | 1.14–1.32 | 1.07–1.25 |
| Yellow-bellied Sapsucker | 4.82–12.50 | 3.22– 7.90 | 0.47–0.77 | 0.34–0.62 |
| Bank Swallow | 13.20–35.10 | 9.21–26.89 | 0.65–1.04 | 0.63–0.98 |
| Blue Jay | 2.85– 7.59 | 2.84– 5.36 | 0.45–0.67 | 0.43–0.64 |
| Common Crow | 27.18–41.80 | 29.53–47.45 | 1.27–1.53 | 1.29–1.51 |
| Robin | 58.49–72.09 | 53.49–67.97 | 1.73–1.84 | 1.68–1.80 |
| Starling | 34.56–54.70 | 34.00–54.54 | 1.30–1.58 | 1.23–1.55 |
| Common Grackle | 12.99–36.33 | 13.89–38.21 | 0.96–1.22 | 1.00–1.26 |
| White-throated Sparrow | 45.21–62.39 | 48.72–66.88 | 1.57–1.73 | 1.63–1.77 |

[a] Total number of comparable routes = 41.

TABLE 4
EFFICIENCY OF THE ESTIMATES OF AVERAGE NUMBER OF BIRDS PER ROUTE AND OF VARIANCE ESTIMATES WITH RESPECT TO THE ESTIMATES MEAN (M) AND VARIANCE (V) BASED ON TRANSFORMED DATA BY SPECIES FOR THE MARITIMES FOR 1971 AND 1972[a]

| Species | Percent efficiency | | | |
|---|---|---|---|---|
| | Average birds per route[a] ($\bar{y}$) | | Variance | |
| | 1971 | 1972 | 1971 | 1972 |
| Common Snipe | 87 | 89 | 14 | 17 |
| Herring Gull | 39 | 32 | 0.03 | 0.01 |
| Least Flycatcher | 95 | 94 | 32 | 28 |
| Tree Swallow | 95 | 94 | 34 | 30 |
| Yellow-bellied Sapsucker | 73 | 77 | 3 | 5 |
| Bank Swallow | 46 | 59 | 0.10 | 0.50 |
| Blue Jay | 89 | 92 | 16 | 23 |
| Common Crow | 82 | 89 | 8 | 16 |
| Robin | 99 | 111 | 66 | 60 |
| Starling | 76 | 66 | 4 | 1 |
| Common Grackle | 81 | 82 | 7 | 8 |
| White-throated Sparrow | 96 | 98 | 39 | 52 |

[a] Total no. of comparable routes = 41.

fidence limits. Similarly, there was no difference between the number of Herring Gulls and Common Crows during 1972 though there was evidence of a real difference on the transformed scale. Again, the number of starlings counted during 1971 was more than Common Grackles as would be evident from the results presented on the logarithmic scale though no such difference was noticeable on the original scale. Tree Swallow and Bank Swallow, Robin and Starling during 1972 may be cited as examples of other cases.

## GAIN IN EFFICIENCY DUE TO TRANSFORMATION

We will now examine if there was any gain in efficiency when the means of the $z$'s where $z = \log_e(y + 1)$ are transformed back into the original variates. This is important since number of birds counted per route can be readily interpreted and is, therefore, more useful to management than its logarithm. The efficiency of $\bar{y}$ with respect to mean $m$ (efficient estimate of $y$) when the means of the logarithm are transformed back is approximately estimated by

$$\frac{\left(s^2 + \frac{s^4}{2}\right)}{e^{s^2} - 1} \qquad (2)$$

where $m$ is approximately equal to $e^{\bar{z}} + \frac{s^2}{2} - 1$ and $s^2$ is an unbiased estimate of $\sigma^2$(var $z$). This follows from a result due to Finney (1941). It would be seen from Table 4 that the efficiency of the direct sample mean was generally high (over 80%) except for Herring Gull, Yellow-bellied Sapsucker, Bank Swallow and Starling for which a logarithmic transformation is recommended. For other species, the mean was satisfactorily estimated by the direct sample mean. Since efficiency will be reduced with increasing values of $\sigma^2$, the above recommendation may not always be the right one and transformation will lead to increased efficiency of the mean for values of $\sigma^2$ exceeding two.

The efficiency of the direct estimates of population variance with respect to an efficient estimate $v$ of the variance of the $y$ population based on the transformed data has been obtained by Finney (1941). The efficiency is approximately estimated by

$$\frac{4s^2(t - 1)^2 + 2s^4(2t - 1)^2}{(t - 1)^2(t^4 + 2t^3 + 3t^2 - 4)} \qquad (3)$$

where $t = e^{s^2}$.

The efficiency given in table 4 ranged from 0.01 to 32 percent except for Robin and White-throated Sparrow for which the efficiency was fairly high and ranged from 39 to 66 percent. The distribution of robins was approximately normal before transformation which explains the high efficiency of the direct estimates of the average number of birds counted per route. Thus, for all the species excepting Robin and White-throated Sparrow, the use of the direct estimate of variance of the $y$ distribution proved very inefficient.

## RELATIVE CHANGE IN ABUNDANCE

One of the main objectives of the study is the detection and measure of relative change in abundance of a species. In this paper we will consider the example of assessing relative change in abundance between two years. However, the results will apply equally to changes between two geographic locations though the latter comparison will be subject to more potential biases. Let $x_i$ denote the number of birds counted by an observer on the $i$th route during a year and $y_i$, the corresponding number of birds counted in another year. Then the estimate of relative change in abundance $\hat{R}$ (expressed as percentage increase) between two years is given by

$$\hat{R} = \left(\frac{\bar{y} - \bar{x}}{\bar{x}}\right)100 = \left(\frac{\bar{y}}{\bar{x}} - 1\right)100 \qquad (4)$$

where $\bar{x}$ = mean number of birds per route in the first year based on the sample of $n$ routes,

TABLE 5
ESTIMATES OF MEAN DIFFERENCE IN BIRDS PER ROUTE, STANDARD ERRORS, $t$ VALUES BOTH ON THE ORIGINAL AS WELL AS LOG SCALE FOR THE DIFFERENT SPECIES IN THE MARITIMES DURING 1971 AND 1972[a]

| | | | $\bar{d}_1$ = (Ave log($\bar{y}$ + 1) − Ave log($\bar{x}$ + 1)) | | | |
|---|---|---|---|---|---|---|
| Species | $\bar{d}(=\bar{y}-\bar{x})$ | SE ($\bar{d}$) | $t$ | $\bar{d}_1$ | SE $\bar{d}_1$ | $t_1$ |
| Common Snipe | −0.30 | 0.94 | −0.41 | −0.01 | 0.06 | −0.23 |
| Herring Gull | 17.29 | 20.32 | 0.85 | 0.12 | 0.08 | 1.50[b] |
| Least Flycatcher | −0.07 | 0.70 | −0.11 | −0.02 | 0.05 | −0.43 |
| Tree Swallow | −2.49 | 2.56 | −0.97 | −0.07 | 0.04 | −1.75* |
| Yellow-bellied Sapsucker | 3.10 | 1.51 | 2.06** | −0.14 | 0.06 | −2.40** |
| Bank Swallow | −6.10 | 5.19 | −1.18 | −0.04 | 0.08 | −0.55 |
| Blue Jay | −1.12 | 1.30 | −0.86 | −0.02 | −0.06 | 0.35 |
| Common Crow | 4.00 | 2.91 | 1.37 | −0.00 | 0.04 | 0.03 |
| Robin | −4.56 | 2.79 | 1.64[b] | −0.04 | −0.02 | 2.36** |
| Starling | −0.37 | 3.46 | −0.11 | −0.05 | 0.04 | −1.06 |
| Common Grackle | 1.39 | 1.33 | 1.05 | 0.04 | 0.04 | 1.02 |
| White-throated Sparrow | 4.00 | 2.16 | 1.85* | 0.05 | 0.03 | 1.56[b] |

* $P < 0.10$.
** $P < 0.05$.
[a] Total no. of comparable routes = 41.
[b] On verge of significance ($P < 0.10$).

and $\bar{y}$ = mean number of birds per route (using same routes as for $\bar{x}$) in another year.

## TEST FOR DETECTION OF RELATIVE CHANGE IN ABUNDANCE

It is obvious from equation (4) that if the number of birds on the routes during one year is different from the number in another year on the same routes, $\hat{R}$ will be significantly different from zero. A test of the hypothesis $\bar{R} = 0$ is equivalent to testing $\bar{Y} = \bar{X}$, where $R$, $\bar{X}$, $\bar{Y}$ are respectively the population versions of $\hat{R}$, $\bar{x}$ and $\bar{y}$ in the sample. We will, therefore use this test both on the original as well as on the transformed scale to detect change in abundance and hence in relative change in abundance between two years. The estimate of the change in abundance, $\bar{d}$, its standard error and the $t$ value between two years is given by

$$\bar{d} = \bar{y} - \bar{x} \qquad (5)$$

$$\text{s.e.}(\bar{d}) = [v(\bar{y}) + v(\bar{x}) - 2\,\text{cov}(\bar{x}, \bar{y})]^{\frac{1}{2}} \qquad (6)$$

$$t = \bar{d}/\text{s.e.}(\bar{d}) \qquad (7)$$

On the transformed scale, the corresponding estimates $\bar{d}_1$, s.e. ($\bar{d}_i$) and $t_i$—values are obtained by substituting $\log_{10}(y + 1)$ and $\log_{10}(x + 1)$ for $y$ and $x$ in the original scale.

It would be seen from Table 5 that the change in abundance measured by the mean difference in birds per route was significant for two of the species and was on the verge of significance ($P < 0.10$) for one; on the logarithmic scale, however, it was significant for three of the species and was on the verge of significance for two other species. Thus, log transformation was more sensitive to detect change in abundance between two years.

## ESTIMATES OF RELATIVE CHANGE IN ABUNDANCE

Expression for the estimate of relative change in abundance $\hat{R}$ was given in equation (4). It can also be interpreted as the percentage increase in the number of birds observed between 1971 and 1972. It is easy to see that the estimate of the standard error (s.e.) of $\hat{R}$ would be given by

$$\text{s.e.}(\hat{R}) = 100\left(\frac{\bar{y}}{\bar{x}}\right)[v(\bar{y})/(\bar{y})^2 + v(\bar{x})/(\bar{x})^2 - 2\,\text{cov}(\bar{x}, \bar{y})/\bar{x}\bar{y}]^{\frac{1}{2}} \qquad (8)$$

The estimates of relative change in abundance, standard error and coefficient of variation for the untransformed as well as transformed data are presented in Table 6. Note that for the transformed data equations (4) and (8) will be replaced by substituting $\bar{z}_1$, for $\bar{x}$ and $\bar{z}_2$ for $\bar{y}$ where $z_1 = \log_{10}(x + 1)$ and $z_2 = \log_{10}(y + 1)$. The conclusions are similar to those obtained in Table 5. Thus, for only three of the species i.e., Yellow-bellied Sapsucker, Robin and White-throated Sparrow, relative change in abundance from 1971 to 1972 was significant, whereas on the transformed scale decrease was, in addition, significant for two other species, i.e., Tree Swallow and Bank Swallow. Thus, the estimates of relative change in abundance on the transformed

TABLE 6

ESTIMATES OF RELATIVE CHANGE IN ABUNDANCE PER ROUTE (R × 100) DURING 1972 OVER 1971, STANDARD ERROR AND COEFFICIENT OF VARIATION (C.V.) WITH CORRESPONDING ESTIMATES BASED ON TRANSFORMED DATA FOR THE MARITIMES[a]

| | Original data | | | Transformed data | | |
|---|---|---|---|---|---|---|
| Species | Relative change in abundance (100R) | Standard error | C.V. | Relative change in abundance | Standard error | C.V. |
| Common Snipe | −8.11 | 16.77 | 2.07 | 1.71 | 9.81 | 5.74 |
| Herring Gull | 60.51 | 62.49 | 1.03 | 12.72 | 8.91 | 0.70 |
| Least Flycatcher | −2.88 | 10.44 | 3.63 | −3.53 | 8.03 | 2.28 |
| Tree Swallow | −10.11 | 11.64 | 1.15 | −5.98** | 2.50 | 0.42 |
| Yellow-bellied Sapsucker | −31.72** | 12.60 | 0.40 | −21.88** | 8.32 | 0.38 |
| Bank Swallow | −27.14 | 18.95 | 0.70 | −5.12** | 1.24 | 0.24 |
| Blue Jay | −22.42 | 22.74 | 1.01 | −4.00 | 14.58 | 3.75 |
| Common Crow | 12.43 | 9.47 | 0.76 | 0.09 | 2.64 | 30.25 |
| Robin | −6.19* | 3.37 | 0.54 | −2.39[b] | 1.44 | 0.60 |
| Starling | −0.62 | 7.67 | 12.47 | −3.28 | 3.10 | 0.95 |
| Common Grackle | 5.64 | 5.42 | 0.96 | 3.72 | 3.74 | 1.01 |
| White-throated Sparrow | 7.04[1] | 4.67 | 0.66 | 2.94[b] | 1.82 | 0.62 |

[a] Total no. of comparable routes = 41.
[b] Verges on significance ($P < 0.10$).
* $P < 0.10$.
** $P < 0.05$.

scale were more precise and able to detect changes between years.

The normal approximation for the ratio estimate $\bar{y}/\bar{x}$, and hence of relative change in abundance, was not realized for almost all the species (excepting Robin and White-throated Sparrow). Also, the sample size ($n = 41$) was not large enough to ensure that the c.v.'s of $\bar{y}$ and $\bar{x}$ are less than 0.1 (Table 1)—a necessary condition for the normal approximation to hold. However, when the data are transformed by taking logarithms, the c.v.'s of transformed means were less than 0.1 in almost all the cases (Table 2); also the sample size was large enough for the normal approximation to hold. The transformed data were, therefore, good enough to provide valid estimates of error for relative changes in the abundance of birds between 1971 and 1972.

## DISCUSSION

The analysis of the data on breeding birds for the Maritime Provinces for 1971–72 has revealed that the abundance of birds for a number of clumped species was highly skewed. Also, in a majority of the cases, the number of routes selected in the region was not large enough to ensure normality of the number of birds per route so that tests based on normal theory tended to be less efficient and sensitive for detecting differences in abundance between any two species for a given season or between any two seasons for a given species.

Logarithmic transformation of the data ensured approximate normality; it resulted not only in some gain in efficiency of the mean but also considerable gain in efficiency of the variance. In all cases, the number of routes selected was large enough to ensure normality of the mean on the logarithmic scale. Also, the estimates of the mean on the transformed scale were more sensitive to detect real differences in the average number of birds counted per route among species than on the original scale.

One of the main objectives of the study was the detection and measure of relative change in abundance of a species between two years. It was shown that the test for detecting relative change in abundance was equivalent to detecting change in abundance.

For some of species, e.g., Tree Swallow and Bank Swallow, the estimates of relative change in number of birds per route were subject to high error and the statistical tests failed to detect real difference between the years. For these species tests based on logarithmic transformation proved valid and more precise to detect the change in abundance.

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